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Equipment for City Milk Plants

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CONTENTS

Page
Introduction 1
Depreciation of milk-plant equipment 2
Weigh can and scales 2
Receiving vat and raw-milk storage tanks 5
  Cooling the raw milk 5
  Storage tanks 6
Milk pumps 8
Clarifier or filter 8
Can washers 10
Pasteurizing and cooling equipment 11
  Heaters 12
  Holders 19
  Coolers 22
  High-temperature, short-time pasteurization 26
  Use of regeneration in heating and cooling milk 26
  Other systems of pasteurization 27
  Materials used in pasteurizing equipment 28
  Factors to be considered in the selection of pasteurizing equipment 28
Fillers and cappers 29
Bottle washers 33
  Bottle-washing solutions 37
Power plant 37
  Steam boilers 37
  Mechanical refrigeration 38
Equipment required for plants of different sizes 41
  Plant of 25 gallons or less 41
  50-gallon plant 43
  100-gallon plant 43
  250- to 300-gallon plant 45
  500-gallon plant 46
  1,000-gallon plant 48
  Plants of large capacity 50
Men required to operate plants equipped at various capacities 51

INTRODUCTION

In making plans for the establishment of a new milk plant or the remodeling of an old one, careful attention should be given to the selection of the equipment to be used. Great progress has been made in the development of milk-plant equipment in the last two decades, and improvements in design are constantly taking place.

The principal improvements in modern well-equipped milk plants, as compared with plants having old-type equipment, are: (1) The equipment is usually more compact in design and requires less space, which is an important consideration in many plants; (2) the milk-handling machinery is in many cases designed to operate at considerably higher speeds, is mostly automatic, and labor-saving devices are more extensively used, so that the output per man-hour is greater; (3) modern milk apparatus generally has fewer and simpler parts designed for accessibility in cleaning, and for easy operation, also the improvements in temperature-control and other regulating devices assist in smoother operation; and (4) more effective utilization is made of metals and alloys that have been found not to impart metallic or other undesirable flavors to the milk, and that have proved durable and lend themselves to easy cleaning.

The purpose of this circular is to describe the principal types of equipment used in milk plants of both large and small capacity. Lists of the principal equipment required for plants of various sizes are given, with the approximate cost.

DEPRECIATION OF MILK-PLANT EQUIPMENT

The life of milk-plant equipment will depend on its original quality, amount of use, and the care given it. As a rule it will receive hard and constant usage, and the annual depreciation will be quite high. Also, the factor of obsolescence must be considered in determining the useful life of milk-plant equipment. With the constant development of more efficient types it is sometimes advisable to procure new and more modern equipment even before the old is worn out.

Table 1 is based on the estimates received from 261 milk-plant operators of the years of useful life for various pieces of equipment at their plants. Although the estimates from different plants varied decidedly, the most common figures given were a useful life of 10 years for washers, fillers, pasteurizers, and coolers. The life of power-plant equipment such as boilers, motors, etc., is usually somewhat longer than that of milk-handling machinery. As a result of improvements in both design and materials used in milk-plant equipment, the average life is somewhat longer than for equipment in use a couple of decades ago.

WEIGH CAN AND SCALES

At very small plants the milk may be weighed in the cans on a set of ordinary platform scales, and in that case no weigh can will be needed. It may then be dumped into the pasteurizing vat (or tank) and the empty cans weighed to determine the net weight of milk. At most plants, however, a weigh can of a single-compartment type (fig. 1) or double-compartment type (fig. 2) is used. One compartment of a two-compartment can may be filled while the other is draining, and much time can be saved where milk is received from a large number of producers. The outlet valves should be large so that the milk will flow out quickly, and they should have convenient levers so that they can be readily opened and closed. Dial scales are used at medium-sized and large plants, so that the operator can quickly note the weight of the milk as it is registered on the dial. Weigh cans or tanks of the suspended type are used in some large plants (figs. 1 and 2). A sample of milk for the butterfat test is taken from the weigh can or tank after each producer's milk has been dumped. Equipment for making the test is shown in figure 3.

At some large plants where the milk is received in tank trucks or tank cars, the milk is weighed in a large, suspended tank from which it is forced by air pressure to the storage tanks.

TABLE 1.—*Estimated useful life of milk-plant equipment at plants of different sizes*

Range in quantity of milk handled daily (gallons)	Plants	Estimated useful life of—														
		Bottle and can washers [1]			Bottle fillers			Pasteurizers			Milk coolers			Power-plant equipment		
		Average	Range	Most common	Average	Range	Most common	Average	Range	Most common	Average	Range	Most common	Average	Range	Most common
	Number	*Years*	*Years*	*Years*	*Years*	*Years*	*Years*	*Years*	*Years*	*Years*	*Years*	*Years*	*Years*	*Years*	*Years*	*Years*
500 or less	42	10.6	3–25	10	11.2	1–25	10	11.0	4–20	10	11.7	5–25	10	12.8	3–20	10
501 to 1,000	38	10.4	5–20	10	10.2	5–15	15	10.2	6–15	10	10.3	5–20	10	13.2	5–25	10
1,001 to 2,000	38	9.8	5–18	10	10.2	6–15	10	9.9	4–15	10	10.4	4–30	10	12.7	6–25	10
2,001 to 3,000	25	10.4	5–18	10	9.4	5–15	10	10.4	4–15	10	9.8	1–15	10	15.2	5–20	15
3,001 to 5,000	41	11.4	5–30	10	10.4	5–30	10	10.4	5–20	10	11.8	5–30	10	15.3	5–25	20
5,001 to 10,000	38	10.4	5–20	10	9.2	5–20	10	9.8	2–20	10	9.6	1–20	10	13.5	8–25	10
10,001 to 20,000	21	11.8	5–20	10	9.8	5–20	10	10.1	5–20	10	9.2	5–15	10	15–8	5–30	20
Over 20,000	18	13.9	7–18	18	9.9	5–15	10	12.1	7–15	15	11.4	7–15	15	18.1	10–25	18
Total or average	261	10.9	3–25	10	10.1	1–30	10	10.4	2–20	10	10.6	1–30	10	14.2	3–30	10

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[1] For most plants the figure reported for bottle washers was the same as for can washers. When separate figures were given, the maximum or bottle-washer figure was used in preparing this tabulation.

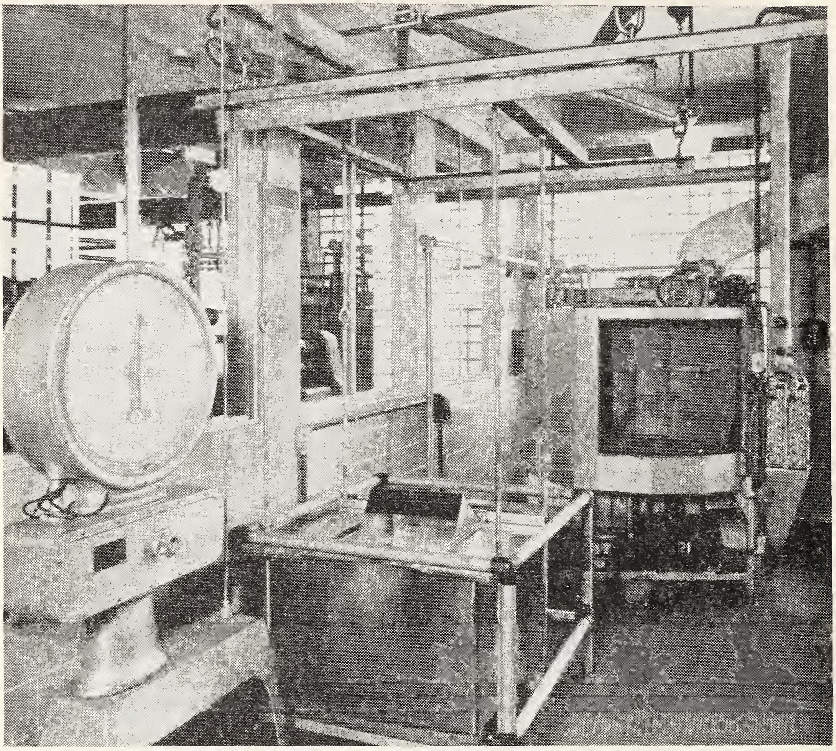

FIGURE 1.—Weigh can (single compartment) and scales, with circular can washer at right.

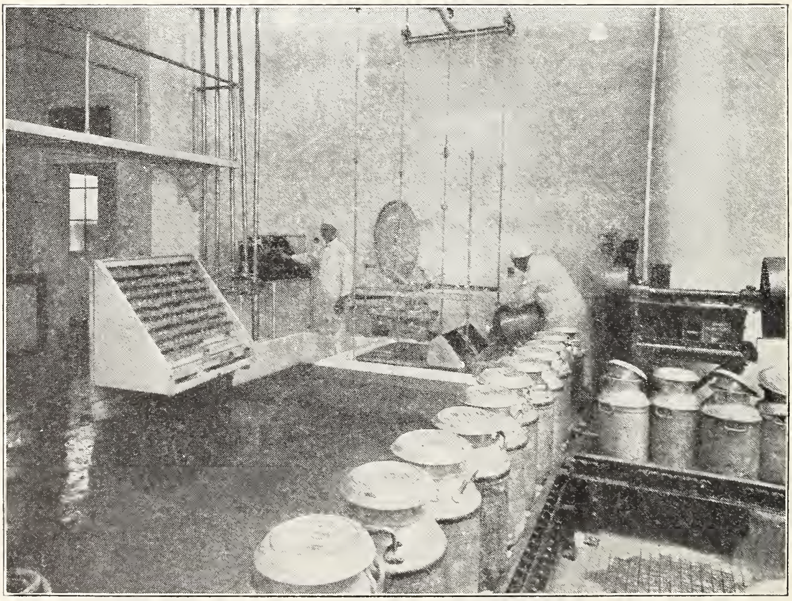

FIGURE 2.—Weigh can (two compartment) and scales in use. Sample rack at left.

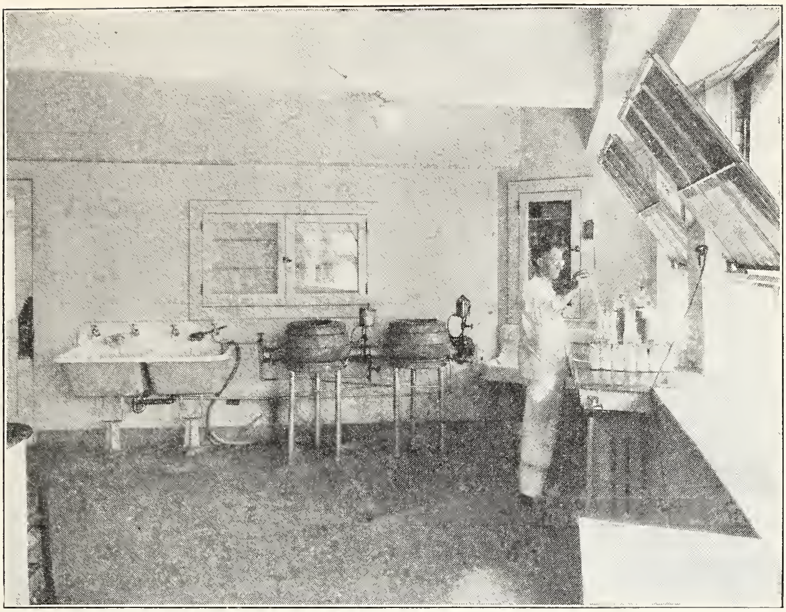

FIGURE 3.—Equipment for making Babcock test for butterfat.

RECEIVING VAT AND RAW-MILK STORAGE TANKS

From the weigh tank the raw milk is released to a receiving vat or tank, from which it is pumped either direct to the pasteurizing department or to storage tanks where it is held before pasteurization. Only a small receiving vat or tank is necessary if the milk can be pumped out as fast as it is received. In small plants where a continuous system of pasteurization is used, the receiving vat should be large enough to hold sufficient milk to keep the pasteurizer constantly supplied with a uniform flow (pp. 7 and 8).

COOLING THE RAW MILK

In case the raw milk is not received at a low temperature, it may be run through a cooler before it goes to the raw-milk storage tanks. It is especially necessary that the milk be cold if it is to be held any length of time before pasteurization. When the milk is cold more heat units will be required to bring it to the pasteurizing temperature, but an equivalent amount of refrigeration will be saved if regeneration is used in pasteurization, as the colder milk reduces the temperature of the hot, pasteurized milk. The use of regeneration in heating and cooling milk is described on pages 26 and 27.

Table 2 shows the methods of receiving the milk at 290 plants of various sizes, with the number that cooled the milk as received. It also indicates the number that used regeneration in pasteurizing the milk. As a rule, regeneration was used more commonly in plants where the milk was cooled before being pasteurized, but it was also used in many cases where the raw milk was received in tanks but was not cooled at the city plant. Of the 41 plants which did not cool the incoming milk and which used regeneration, 15 received the milk in tanks; whereas of 59 that cooled the incoming milk and used regeneration, only 8 received the milk in tanks. There were 133 plants which did not cool the incoming milk and which did not use regeneration. At all of these the milk was received in cans. Where tanks are used to transport the milk, it usually arrives at the plant at a lower temperature than where cans are used, so that precooling is not necessary.

TABLE 2.—*Methods of receiving milk and systems of regeneration used in pasteurization plants of different sizes*

Range in quantity of milk received daily (gallons)	Plants	Milk received daily per plant	Plants receiving milk in cans	Plants receiving milk in tanks	Plants cooling milk before processing	Plants using regenerative system indicated		
						None	Milk-to-milk regeneration	Milk-to-water-to milk regeneration
	Number	*Gallons*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
500 or less	47	329.5	47	0	5	39	1	7
501 to 1,000	43	766.6	42	1	6	37	1	5
1,001 to 2,000	38	1,343.7	36	2	7	31	1	6
2,001 to 3,000	26	2,509.9	24	2	5	20	5	1
3,001 to 5,000	42	4,141.3	[1] 37	[1] 6	17	24	7	11
5,001 to 10,000	41	7,304.9	[1] 39	[1] 10	19	29	10	2
10,001 to 20,000	22	15,060.4	[1] 18	[1] 9	14	7	10	5
Over 20,000	31	28,909.6	[1] 11	[1] 22	12	3	18	10
Total	290		[1] 254	[1] 52	85	190	53	47

[1] Some of the plants received milk in both cans and tanks.

STORAGE TANKS

At plants of medium and large size, specially constructed storage tanks are used for the incoming raw milk. These tanks are usually constructed of stainless steel or of glass-lined steel, and are so insulated that the temperature of the milk can be maintained. The tanks may be installed either vertically or horizontally. Horizontal tanks have the advantage of being more accessible for cleaning (fig. 4) and of requiring less head room. A tank of this type vertically installed may be used as a weigh tank in large plants where the milk is received in tank trucks or tank cars. The milk is lifted from the weigh tank to the other tanks by compressed air or vacuum. In plants with more than one story, the raw-milk storage tanks may be on the same floor as the weigh tank or they may be in the pasteurizing room on an upper floor level. Where they are on the lower level the milk may be lifted by air from them to the pasteurizing department. As considerable air pressure is required, the tanks must be of sturdy construction.

The number of plants of various sizes that had raw-milk storage tanks, and the total raw-milk storage capacity in each group, are shown in table 3. The plants are also classified by types of pasteurizers used.

It will be noted that for both large and small plants some raw-milk storage capacity is usually required where the continuous-flow system of pasteurization is used. Where the batch system is used the milk may go directly from the receiving vat or tank to the pasteurizing vats or tanks with no intermediate storage. This is especially true

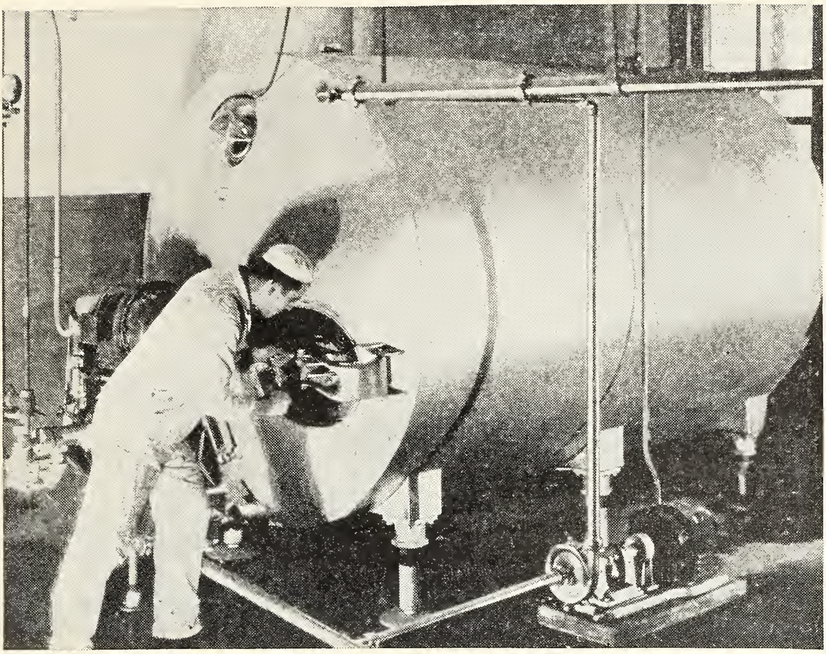

FIGURE 4.—Horizontal storage tank for raw milk.

TABLE 3.—*Relation of type of pasteurizing equipment to amount of raw-milk storage capacity at plants of different sizes*

Range in quantity of milk handled daily (gallons)	Plants using batch pasteurizers					Plants using continuous-flow pasteurizers				
	Plants	Milk handled daily per plant	Storage capacity per gallon of milk handled	Plants having raw-milk storage tanks		Plants	Milk handled daily per plant	Storage capacity per gallon of milk handled	Plants having raw-milk storage tanks	
				Plants	Storage capacity per plant				Plants	Storage capacity per plant
	Number	*Gallons*	*Gallons*	*Number*	*Gallons*	*Number*	*Gallons*	*Gallons*	*Number*	*Gallons*
500 or less	44	321	0. 11	7	222	3	350	0. 38	2	200
501 to 1,000	30	730	. 18	5	788	11	809	. 70	11	566
1,001 to 2,000	20	1, 615	. 07	3	754	19	1, 598	. 61	16	1, 158
2,001 to 3,000	10	2, 523	. 12	2	1, 514	14	2, 446	. 85	13	2, 239
3.001 to 5,000	8	4, 199	. 23	5	1, 545	34	4, 127	. 82	33	3, 487
5,001 to 10,000	8	7, 470	. 42	5	5, 020	29	7, 264	. 76	29	5, 521
10,001 to 20,000	1	12, 573	0	0	0	20	15, 363	. 68	20	10, 447
Over 20,000	--------	--------	--------	--------	--------	27	29, 539	. 91	27	26, 880

at small plants, where it is usually unnecessary to hold the milk for any length of time. Few of the smaller plants using the batch system had any raw-milk storage tanks. Most large plants, however, need some raw-milk storage capacity even with batch pasteurization, because it is usually desirable to carry some raw milk over to avoid any delay in the operation of the pasteurizing department in case of late arrival of the next day's supply.

The storage capacity per gallon of milk received in each group, as shown in table 3 (page 7), is much greater for all groups of plants where the continuous system of pasteurization is used than with the batch system. Raw-milk storage tanks of capacities from 100 up to 16,000 or more gallons are used. The milk-supply pipe leading to these tanks should extend to the bottom of the tank to avoid formation of foam.

MILK PUMPS

Pumps are required to transfer the milk from one piece of equipment to another. Milk pumps can be obtained that keep churning of the milk and resulting formation of foam to a minimum. The centrifugal pump may be used where the milk flows directly to the pump. It will lift the milk several feet and is satisfactory for pumping it over or through the cooler, provided the pump is so placed that the milk flows to it. Other common types are the piston and the rotary pumps, the latter being adaptable where suction is required. Milk pumps should be of simple construction so that they can be readily taken apart for cleaning.

CLARIFIER OR FILTER

In order that the milk may be free from any foreign matter such as small particles of dirt, etc., it is usually filtered or clarified at the city plant. Of a total of 297 plants, 246 used filters (figs. 6 and 9), 38 used clarifiers, and only 13 did not use a filter or clarifier.

The clarifier removes foreign particles from the milk by centrifugal force. Formerly milk was preheated to about 85° or 95° F. before clarifying, both because it was believed that better clarifying results were obtained and because less foam resulted at these temperatures. Clarifiers have been recently developed, however, which produce satisfactory results at low temperatures and do not cause much foam.

Table 4 shows the temperature at which milk was clarified at the 38 plants that had clarifiers; only 4 of these preheated the milk before clarifying. Clarifying the cold, raw milk has practically no effect on the creaming ability of the milk. Clarifying at higher temperatures some-

TABLE 4.—*Number of plants of different sizes clarifying milk at specified stages and temperatures*

Range in quantity of milk received daily (gallons)	Plants	Temperature used in plants at which milk was clarified—							
		At or near receiving temperature				After preheating			
		Plants	Average	Range	Most common	Plants	Average	Range	Most common
	Number	*Number*	° *F.*	° *F.*	° *F.*	*Number*	° *F.*	° *F.*	° *F.*
500 or less	2	2	45.0	40-50					
501 to 1,000	1					1	85		
1,001 to 2,000	4	4	55.0	40-70					
2,001 to 3,000	1	1	50.0						
3,001 to 5,000	9	7	49.1	36-60	50	2	112	90-134	
5,001 to 10,000	10	9	47.1	38-60	55	1	95		
10,001 to 20,000	5	5	45.4	40-60	40				
Over 20,000	6	6	43.0	40-46	45				
Total, average, or range	38	34	47.5	36-70	45	4	101	85-134	

times results in an apparent loss of cream volume, which may be restored by subsequent pasteurization if the milk is not agitated too severely after being clarified. The capacity of the clarifier should be large enough to permit a maximum, uniform flow of milk to the pasteurizer and bottle-filling equipment.

Various types of milk filters are available. With most types the milk is pumped through the filter and any sediment intercepted drops at once into a trap so that the milk does not constantly pass through it. In many small plants only a home-made filter is used and this is installed at the dump tank. It may be simply a metal frame that holds the filter cloth (or sterile cotton) between two layers of cheesecloth. A special filter cloth is used with commercial filters. This cloth usually consists of special long-napped flannel material. The long nap may be only on one side (that which receives the milk) but usually is on both sides of the cloth. Special enclosed filters are generally used at large plants, and these are often installed in a series of two or more so that one may be cut out during the run and its cloth changed without shutting down. Since any filter will be less efficient after a limited period of use, when long runs are made the cloths must be changed occasionally. The cloths should not be used a second time. Some of the smaller plants have a filter that is inserted in the sanitary pipe line. This type of filter can be obtained with a diameter as small as 1½ inches, and by the use of proper fittings can be attached to a 1-inch sanitary line.

As a rule filtering can be done efficiently after the milk has been preheated to about 90° to 100° F., but there are available filters designed to filter the cold, raw milk as received. Some of these can do very good work. In some cases the milk is filtered at or near the pasteurizing temperature. Though hot milk can be filtered efficiently, this should never be done after the pasteurizing process has been completed; where the pasteurizing temperature is used the filter may be placed between the heater and the holder. Some boards of health require that the milk either be filtered cold or clarified.

The temperatures at which milk was filtered at 246 plants are shown in table 5.

TABLE 5.—*Number of plants of different sizes filtering milk at specified stages and temperatures*

Range in quantity of milk received daily (gallons)	Plants	Temperature used in plants at which milk was filtered—											
		At or near receiving temperature				After preheating				At or near the pasteurizing temperature			
		Plants	Average	Range	Most common	Plants	Average	Range	Most common	Plants	Average	Range	Most common
	No.	*No.*	° *F.*	° *F.*	° *F.*	*No.*	° *F.*	° *F.*	° *F.*	*No.*	° *F.*	° *F.*	° *F.*
500 or less	41	19	49.8	40–60	50	15	100.0	70–130	90	7	142.0	140–144	142
501 to 1,000	37	18	50.3	40–60	50	12	107.9	70–130	120	7	141.7	138–146	143
1,001 to 2,000	34	10	53.0	45–60	50	15	110.3	70–135	130	9	143.0	140–145	143
2,001 to 3,000	27	10	50.3	40–60	50	10	105.9	90–135	90	7	143.7	142–145	145
3,001 to 5,000	33	10	52.6	40–60	60	19	104.4	85–135	120	4	142.0	140–145	140
5,001 to 10,000	31	7	54.3	45–65	60	18	111.7	90–130	120	6	141.5	138–144	142
10,001 to 20,000	18	1	45.0	------	----	14	111.4	90–135	110	3	143.0	142–144	----
Over 20,000	25	2	45.0	------	45	21	99.9	60–125	120	2	143.0	--------	143
Total, average, or range	246	77	51.0	40–65	50	124	106.1	70–135	120	45	142.5	138–146	143

Many of the 77 plants that filtered the milk cold were small ones that used home-made filters at the weigh can or filters specially constructed to filter cold milk. The 124 plants where the milk was preheated before being filtered showed a considerable range in preheating temperature, in all sizes of plants; only 45 filtered the milk at or near the pasteurizing temperature.

Filtering has very little effect on the cream line of the milk, but the tendency to injure the cream line increases with an increase in the filtering temperature, if accompanied by agitation.

CAN WASHERS

Can washing is one of the most important operations in the milk plant, for unless the cans are thoroughly cleaned the quality of the milk will be impaired.

At very small plants the cans may be washed by brushing. The cans are first rinsed in cold or lukewarm water to remove milk adhering to them. After this the can is placed in a vat or tank and is thoroughly brushed inside and out with hot water to which the washing powder has been added. The can is then rinsed with hot water, and finally is placed over a steam jet and treated with live steam. Each can should be steamed at least 30 seconds or until it will dry quickly. Very satisfactory results may be obtained with this system of washing cans if it is properly done.

Because of the greater rapidity with which the cans can be washed and to save labor, some type of mechanical washer is generally used in most plants except the very small ones. Mechanical can washers can be obtained in various sizes, depending on the number of cans to be washed daily. Such washers subject the cans to a continuous series of rinsings and washing solutions, which differ in number and variety according to the design and capacity or size of the machines. The rinsing, washing, and final treatment are applied with powerful sprays or jets as the cans pass through the machine. Mechanical washers may be of either the circular type, in which the can while being cleaned makes a complete rotation in the machine, or the straight-away type, which delivers the can at the opposite end of the washer. Circular-type machines are used at both large and small plants, but straight-away washers are used more in the large than in the smaller plants. In mechanical washers the lids receive the same treatment as the cans.

In the larger mechanical washers, the cans are subjected to many successive sprays of cold or lukewarm water, increasingly hotter washing solutions, and still hotter rinse waters, somewhat similar to the treatment of bottles in an hydraulic bottle washer (p. 33). After the cans have been washed and rinsed, they receive sprays of scalding water or steam. The treatment with water near the boiling point is probably as effective as that with steam. As a final treatment the cans are dried by forcing a blast of air over inclosed steam coils and through air jets into the cans. This drying is very important, as the cans must be thoroughly dry to prevent both bacterial growth and rusting, thus prolonging the life of the can. In many of these machines the covers and the cans receive as many as 12 treatments, including washing, rinsing, steaming, and drying. With proper hot-air drying the covers can be placed on the cans instantly, as they retain no moisture. In many machines the can is discharged right side up with the lid in place, thus preventing any possible subsequent contamination of the inside of the can.

With the straight-away type the man who dumps the milk places the can in the washer, and as the washed can is discharged at the opposite end more than one man may be required to operate the machine, if the covers must be placed on the cans. In many of these machines the can with lid on is discharged to a conveyor that carries it back to the hauling truck. Such a machine can be operated by one man. The circular or rotary-type washer (fig. 1) can also be operated by one man who, while standing still, removes one washed can and lid from the machine and puts in another to be washed.

In a survey of about 300 plants of various sizes it was found that many plants handling less than 500 gallons of milk daily did not have a mechanical washer, but washed the cans by brushing. In some cases the cans were simply rinsed with cold water and steamed over a steam jet. Various small washers were also used, some of them being home-made. Some of the plants in this group used rotary, automatic washers, somewhat similar in operation to the circular, or rotary, washers used in larger plants. In the group handling between 500 and 1,000 gallons of milk daily, 1 straight-away washer was observed, and most of the other plants of this size had rotary washers. In the group handling between 1,000 and 2,000 and the group handling between 2,000 and 3,000 gallons daily, each had 6 plants with straight-away washers and most of the other plants used rotary machines. In the 3,000- to 5,000-gallon group, there were 15 straight-away washers in a total of 38 plants, all the others using rotary washers. In the groups handling between 5,000 and 10,000 and 10,000 and 20,000 gallons about one-third used straight-away and two-thirds had rotary washers, while in the group of plants handling over 20,000 gallons daily about half of the plants used straight-away and half used rotary machines.

On an average, the straight-away washers are of greater capacities than those of the rotary type, but the latter have the advantage of requiring less floor space than a straight-away of about the same capacity.

With the straight-away type, the can after it has drained at the weigh tank is pushed directly into the machine. There may be a device at the entrance of the machine to catch any milk remaining in the can. If such a device is not present and it is not practicable to allow the cans to drain thoroughly at the weigh tank, some form of drip pan would save a considerable quantity of milk over a period of time.

PASTEURIZING AND COOLING EQUIPMENT

At present two processes are in common use for pasteurizing milk for direct consumption, the holder process and the high-temperature, short-time process. The means with which either of these processes are accomplished in milk plants vary according to the various systems used for heating the milk to the pasteurizing temperature and cooling the milk. The different heating and cooling systems in use depend largely on the type of pasteurizing equipment selected as well as the process of pasteurization to be used. Some types of pasteurizers are adapted to either process.

With the holder process every particle of milk should be heated and held at a temperature of 142° to 145° F. for not less than 30 minutes. The temperatures at which milk is pasteurized at 276 plants using the holder process are shown in table 6, the most common temperature reported being 143° and the average for all plants being slightly above 143°. The holder process is also called low-temperature pasteurization.

Previous to about 1907 milk was sometimes pasteurized at high temperatures by the flash process with no holding. This process was almost entirely replaced by the holder process, which is most commonly used in the United States.

The high-temperature, short-time process is a relatively recent development. When it is properly carried out, the milk is heated approximately to 162° F. and held at that temperature for a period of about 15 seconds. It has been perfected in recent years so that the temperatures are accurately controlled, and several States and municipalities now permit its use. In 13 plants, varying in size from 200 to over 20,000 gallons daily, which reported its use, the average pasteurizing temperature used was 161.3°, varying from 156° to 162°. Five of these plants used 160° and four used 162°.

TABLE 6.—*Pasteurizing temperatures used at 276 plants of different sizes with the holder process*

Range in quantity of milk handled daily (gallons)	Plants	Milk handled daily per plant	Temperature of pasteurization			
			Average	Range	Median	Most common
	Number	*Gallons*	*°F.*	*°F.*	*°F.*	*°F.*
500 or less	46	332	143. 3	140–146	143	143
501 to 1,000	41	766	143. 5	142–146	143. 5	143
1,001 to 2,000	37	1, 350	143. 4	142–145	144	143
2,001 to 3,000	25	2, 500	143. 7	142–145	144	145
3,001 to 5,000	41	4, 167	143. 6	142–145	143	143
5,001 to 10,000	38	7, 422	143. 4	142–145	143	143
10,001 to 20,000	19	15, 086	143. 7	142–145	143. 5	144
Over 20,000	29	29, 214	143. 8	142–145	143. 5	144

The types of pasteurizing equipment used in the 13 plants were (1) the electric-heater system, (2) plate heat exchangers, and (3) internal-tubular heaters. These heating systems are also used with the low-temperature or holder process, and are described under Heaters. With the high-temperature, short-time process no separate apparatus is required for holding the milk, but with the holder process special holders are used, although with some types of pasteurizing equipment the milk is heated and held in the same apparatus.

HEATERS

In general there are two types of heaters—batch and continuous-flow. Batch heaters consist of tanks or vats in which the milk remains with only gentle agitation while it is being heated. They are used only with the holder process of pasteurization. Holding is accomplished in the same vat or tank. With continuous-flow heaters the milk is heated as it passes continuously through the apparatus. Continuous-flow heaters are extensively used with the holder process and the milk, after passing through the heater, goes to a holder in which it is held 30 minutes before it goes to the cooler. With the high-temperature, short-time process continuous heaters must be used in which the milk is heated to the pasteurizing temperature and held about 15 seconds, which is the time required for it to pass through the apparatus after it reaches the pasteurizing temperature, and then goes directly to the cooler.

BATCH HEATERS

Batch heaters may be classified as (1) coil vats, (2) spray vats, and (3) tank heaters or pasteurizers. The vat or tank may also be used for holding the milk after it has been heated to the pasteurizing temperature, and thus serves as a complete pasteurizer, no separate holder being required.

Coil vats (figs. 5 and 23) consist of rectangular or square vats in which a coil containing the heating medium is revolved when the milk is being heated or held. The heating medium is water that has been heated in a separate compartment and is forced through the coil. The milk is gently agitated by the revolving coil so that it is heated uniformly throughout the vat. These vats are insulated with corkboard to prevent loss of heat by radiation. Originally all coil vats were rectangular and the coil was hung horizontally, but at present square vats with the coil hung vertically are commonly used also. The latter type has the advantage that the bearings and stuffing box are located above the cover of the vat, and thus no milk can get into them, as might be possible with a vat having the stuffing box attached at a point on the outside but below the milk level that is inside. The inner lining of the vat may be tinned copper, stainless steel, or glass-lined steel. The covering of sides and bottom, outside of the insulating material, is usually of wood or steel and may be finished with enamel. A small tank, which may be separate from the pasteurizing vat or a compartment in it, contains the heating medium, which is hot water. The temperature of the medium is controlled automatically.

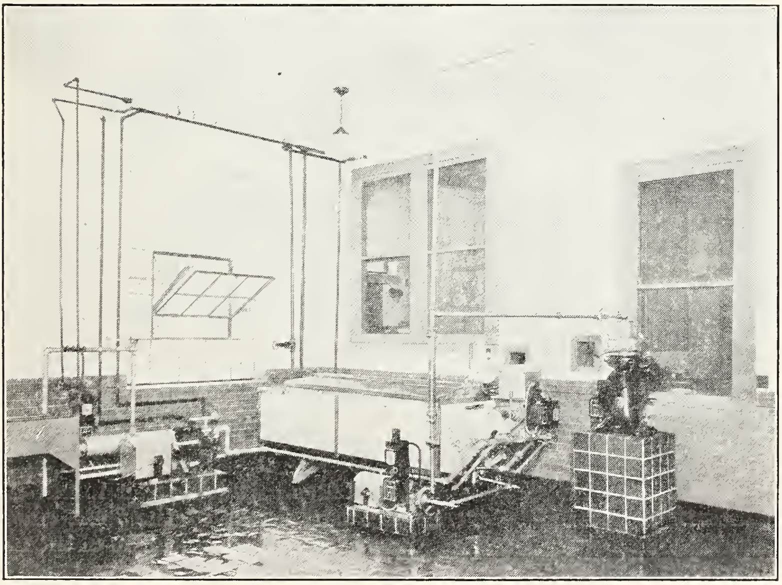

Figure 5.—Vat pasteurizer of the coil type in a small plant.

Spray vats (fig. 6) are double-walled, jacketed vats wherein the milk is heated by spraying hot water against the side of the inner vat by means of a pump. The milk is agitated by slowly moving paddles or blades controlled by a mechanism on the top frame of the vat. This type of vat is usually long and narrow in shape and can be cleaned easily, as the sides are readily accessible and there are no coils. The materials used for the inner tank are similar to those used in coil vats. The outside wall of the vat is usually of steel and may be finished with aluminum or porcelain enamel.

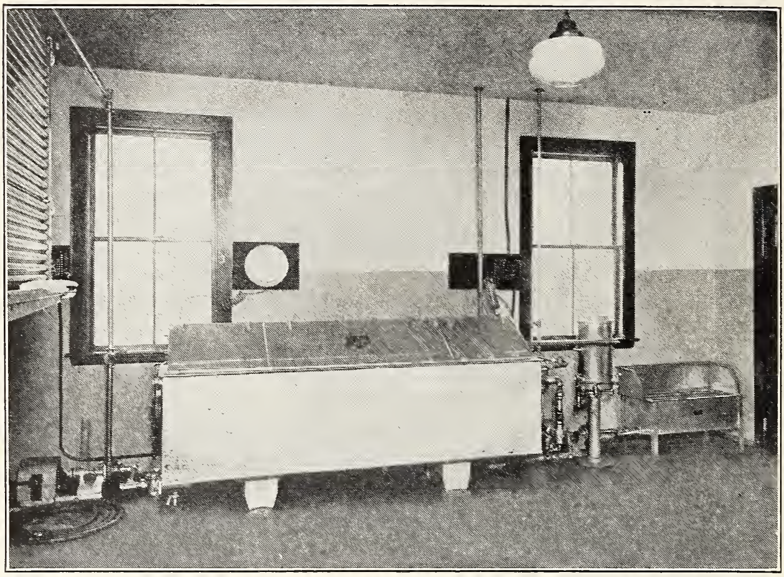

FIGURE 6.—Pasteurizer of the spray-vat type, dump tank, pump for raw milk, and filter at right, pump for pasteurized milk, and cooler at left.

Tank pasteurizers (figs. 7, 21, 22, and 24) are double-walled tanks. The inner tank may be of tinned copper, glass-lined steel, or stainless steel. The outer tank is usually of steel, with corkboard insulation. The heating medium is introduced into the space between the two tanks, and the heat is transferred to the milk through the wall of the inner tank. Where hot water is used as the heating medium it flows over the walls of the inner tank in a thin film. The circulation of the hot water may be by a pump or by a steam jet. As the water falls to the bottom of the apparatus, it is recirculated after being automatically brought up to the proper temperature, which is only a few degrees above that of the milk. The milk is agitated by a propeller attached at the side of the tank near the bottom or in some types by a revolving paddle which is controlled by a mechanism at the top of the tank. With some of these tanks low-pressure steam is used as the heating medium. The steam condenses as soon as it strikes the wall of the tank containing the milk, which is colder. It has been found that satisfactory results as to cream line and flavor of the milk can be obtained by using steam in this way, provided the agitation of the milk is sufficient to effect a rapid heat transfer. Some tank pasteurizers are similar in construction to those described above, except that a vertically hung heating coil is used to circulate the heating medium.

Tank pasteurizers are available in capacities as small as 50 gallons, and even 25 gallons can be pasteurized in the 50-gallon tank. They are especially adaptable for small units (figs. 7, 21, and 22). As tank pasteurizers require considerable floor space and time for heating the milk where large quantities are to be pasteurized, large plants usually use some other method of heating the milk. Tanks of similar construction, however, are widely used at large plants as holders for the milk after it has been heated to the pasteurizing temperature.

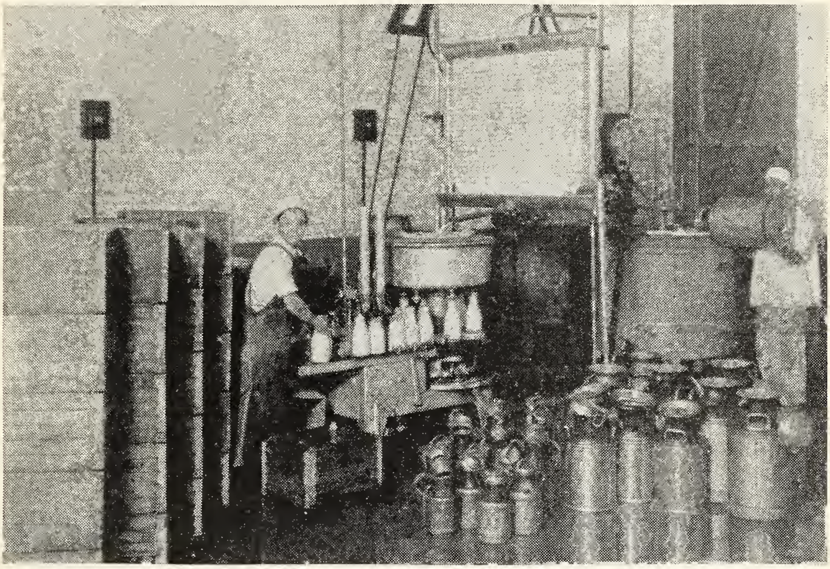

Figure 7.—Tank pasteurizer surface cooler, and rotary filler in a small plant The raw milk is being dumped directly into the pasteurizer, a practice not permitted by some health authorities.

USE OF BATCH PASTEURIZERS

Batch pasteurizers, owing to their simple construction and ease of operation, are especially adapted to small plants. At some small plants the incoming milk is dumped directly from the cans through a filter into the pasteurizer, as in figure 7, which thus serves also as a receiving tank. The same vat or tank may also be used for the processing of other products, as cream and chocolate drink, if desired. As the output of the plant increases, the capacity for pasteurizing can be readily increased by purchasing additional vats or tanks. The covers of these should be kept tightly closed to prevent evaporation of the milk and contamination from outside air. It is important that the coils or propellers revolve at the rate of speed recommended by the manufacturers, as too high a speed may injure the cream line.

Although batch pasteurizers are not generally used for heating the milk by large plants where a large quantity of milk must be pasteurized in a short time, and with the use of a comparatively small floor space, such vats or tanks are used extensively as holders for the milk during the 30-minute holding period (see p. 19). For plants of medium size a practically continuous system of pasteurization may be obtained by the use of a battery of three or more vats or tanks.

Table 7 shows that at 134 plants using batch pasteurizers, 80 used spray vats, 30 coil vats, and 24 tanks for heating the milk. In most cases these were used at the smaller plants.

TABLE 7.—*Number of plants of different sizes using specified types of pasteurizers for heating milk*

Range in quantity of milk handled daily (gallons)	Plants	Plants using specified type of batch heater			Plants using specified type of continuous-flow heater					
		Coil vat	Spray vat	Tank	Danish or kettle	Barrel	Internal-tubular	Surface-tubular [1]	Electric	Plate heat exchanger
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
500 or less	47	9	23	9	--------	--------	5	--------	1	--------
501 to 1,000	46	10	21	2	--------	3	8	--------	1	1
1,001 to 2,000	43	5	15	4	--------	3	15	--------	1	--------
2,001 to 3,000	31	2	8	3	--------	--------	14	--------	1	3
3,001 to 5,000	46	3	5	1	--------	2	29	1	--------	5
5,001 to 10,000	43	--------	6	3	2	4	22	1	1	4
10,001 to 20,000	26	1	1	2	--------	1	12	2	--------	7
Over 20,000	34	--------	1	--------	--------	4	14	8	--------	7
Total	316	30	80	24	2	17	119	12	5	27

[1] Includes plants using cabinet or fan type of surface cooler.

CONTINUOUS-FLOW HEATERS

In general continuous-flow heaters are of greater capacity for the floor space required than batch heaters, because less time is required for heating the milk to pasteurizing temperature, and a large quantity can be pasteurized quickly with a comparatively small floor area. The principal types of continuous-flow heaters are: (1) Danish or kettle-type heater, (2) barrel-type heater, (3) internal-tubular heater, (4) surface-tubular heater, and (5) plate heat exchanger.

The Danish or kettle heater is probably the oldest type of heater now in use, as this type was first used in the United States in 1895. Since that time many improvements have been made, but the principle is the same as with the original heater. It consists of a jacketed kettlelike chamber or cylinder, heated with condensed steam, with rapidly revolving paddles that whirl the milk against the walls and out the top of the cylinder. In this heater live steam is introduced into the jacket at a point near the bottom, and the first steam condenses on the cold wall of the inner cylinder containing the milk. The water formed by the condensation soon fills the space between the inner and outer cylinders and is kept at the desired temperature by more live steam, the temperature being controlled automatically. The milk enters the inner compartment or cylinder at a point near the bottom, and when thrown against the walls of the cylinder by the rapidly revolving paddles is quickly heated to the pasteurizing temperature. The force generated by the rapidly revolving paddles is so great that it pumps the milk through the outlet, and will raise it through a pipe as much as 15 feet if desired. This type of heater occupies a small floor area and is readily accessible for cleaning.

The barrel-type heater (figs. 8 and 9) consists of a series of seamless tubes connected at each end by heads or return bends, enclosed in a barrellike frame. The milk is pumped through the tubes; it enters at the bottom and is forced continuously through the tubes until it comes

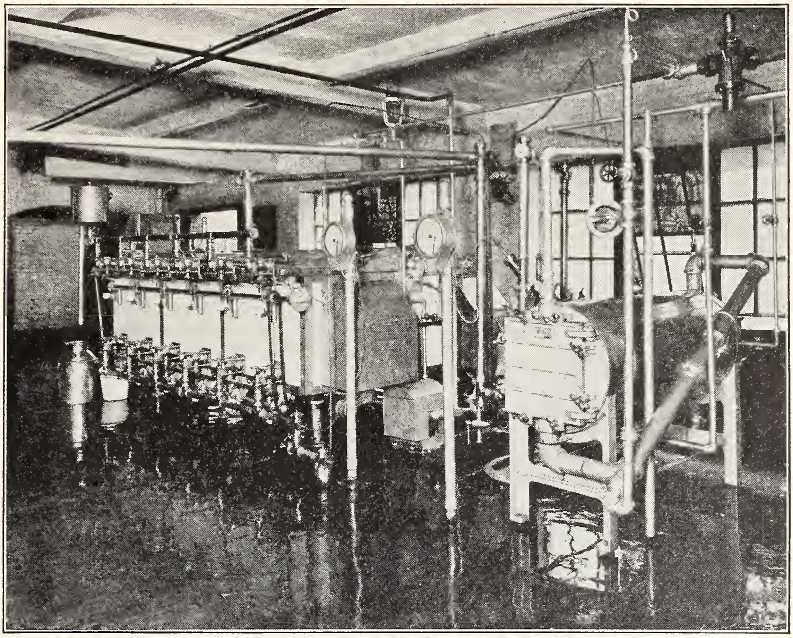

Figure 8.—A barrel-type heater, right, with a holder of the stationary pocket type, left.

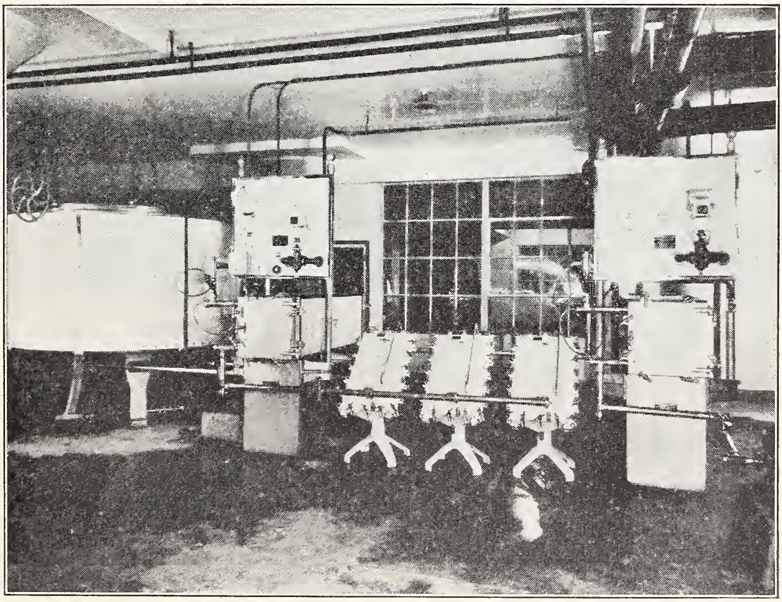

Figure 9.—Revolving, pocket-type holder, left, with a barrel heater and filters at right.

out at the top. The tubes are surrounded by water which is heated by live steam, the heater being automatically controlled. Like the Danish type, this heater uses a relatively small floor area, and is easily cleaned, as the area with which the milk comes in contact is not great; a high-temperature heating medium is required, and accurate temperature control is necessary with both types. Barrel and Danish-type heaters are often used in connection with a regenerator, so that the heater itself has only to heat the milk from approximately 100° F. to the pasteurizing temperature and the quantity pasteurized per hour is thereby increased. These heaters may be used with any type of holder.

Internal-tubular heaters (figs. 10 and 12) have a series of tubes inside other tubes or a jacket, and the heating medium travels countercurrent to the milk flowing through the inner tubes. The heating medium is hot water, and its temperature is automatically maintained by the introduction of steam before the water enters the tubes.

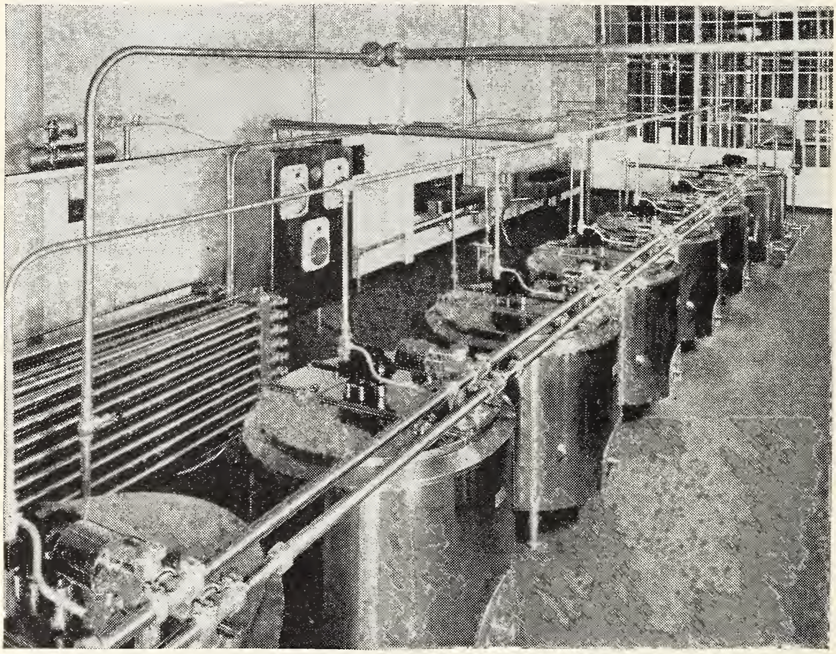

Figure 10.—Tank holding system automatically operated, with a capacity of 14,000 pounds per hour; internal-tubular heater at left.

Regeneration is generally used to preheat the milk by passing the water from the cooler, which has been heated by the hot, pasteurized milk, through the first section of the heater. Where filters are used they are generally placed between this preheater and the heater proper. This is discussed more fully later under regeneration.

Surface-tubular heaters are similar to surface-tubular coolers, hot water being forced through the inside of the tubes as the raw milk flows over the outside in a thin film. The data in table 7 (p. 16) indicate that this type of heater is used more at the larger than at the smaller plants. In large plants where milk is heated by this system, it may be preheated by regeneration either from milk to milk or from milk to water to milk (pp. 26 and 27). Many of these heaters are of the cabinet type, also called the wing or fan type, and require only a small floor area. They are usually covered to prevent contamination from outside air and to keep evaporation at a minimum.

The manufacture and use of plate heat exchangers for heating milk are a comparatively recent development in the United States, although heaters of this type have been used for a number of years in England, where the first heater of this type was developed in 1923. This apparatus consists of a series of thin metal plates with grooves or troughs and with ports, so arranged that the milk passes in a thin film on one side of the plates and the heating medium flows on the other side in the opposite direction to the milk flow. The plates needed for the desired capacity are assembled into a unit. The milk is forced continuously from one plate to the next through the unit; the edges of the plates have rubber gaskets to form a tight joint. The joints or contacts are so constructed that if any leak should occur it will pass out through special grooves, so that there can be no mixture of milk and heating medium passing through the heater. When such a heater is used with the holder process of pasteurization, the hot, pasteurized milk from the holder may be returned through the first section of the heater countercurrent to the incoming raw milk on the opposite side of the plates and preheat the raw milk and is thus itself precooled by the raw milk. Final cooling is accomplished by more plates with cold water or brine or a combination of the two as the cooling medium.

Plate heat exchangers are especially adapted to milk-to-milk regeneration and the exchange of heat between the cold and hot milk is very efficient, as there is practically no loss of heat by radiation. The milk is completely enclosed during both heating and cooling, so that there is practically no opportunity for contamination from outside air or for evaporation. The plates are readily accessible for cleaning, and can be effectively treated to kill bacteria by pumping either hot water or a chemical solution through the apparatus. The machine is very compact and requires only a small floor space. This type of pasteurizer is especially adapted for the high-temperature, short-time process. It is used in plants of nearly all sizes but more commonly at the larger plants, as shown in table 7.

HOLDERS

In general there are three types of holders: (1) Batch holders, (2) pocket holders, and (3) continuous-flow holders.

BATCH HOLDERS

Batch holders are vats or tanks similar to those described under heaters. At small plants they are used as heaters also, and after the milk has been heated to the pasteurizing temperature the circulation of the heating medium is stopped and the milk is held in the same vat or tank 30 minutes (figs. 21, 22, and 23). It is then cooled over a separate cooler. The coil in coil vats is usually allowed to revolve during the holding period. If automatic temperature control is not provided and the temperature of the milk in the vat should fall below the pasteurizing temperature, as indicated by the recording thermometer chart, the steam valve may be "cracked" momentarily so that the pasteurizing temperature is maintained during the entire holding period. Vats and tanks are usually well insulated, so that practically no heat is lost by radiation. The covers should be kept closed to avoid contamination from outside air and keep evaporation at a minimum. While some agitation is desirable during the holding period to maintain a uniform temperature throughout the milk and also to prevent cream from rising, the "slow" speed of the coil or propeller is sufficient where two speeds are provided. If the milk after being heated and held 30 minutes is precooled in the vat or tank to about 115° F. before it is pumped to the cooler, none can be held at the pasteurizing temperature over the 30-minute period, and the exact time that the milk was held at the pasteurizing temperature will be indicated on the thermometer chart. Cooling below about 115° in the vat or tank, however, may injure the cream line of the milk. Where the milk is not precooled the first milk pumped to the cooler will be held 30 minutes, and the holding time varies for the rest of the batch.

For medium-sized plants a battery of three or more vats or tanks, as was stated under heaters, can be used to provide a continuous flow of milk to the cooler, if the heating, holding, and emptying of the different vats is performed at definite, predetermined intervals. Vats or tanks in batteries are widely used by large plants as holders (fig. 10). Automatic, electrical control is provided to regulate the timing and operating of the valves which control the inflow and discharge of the milk. These holders vary in size from 100 to 500 or more gallons, and batteries of from three to eight may be used, depending on the capacity required. Usually not more than six are used per unit, and for smaller capacities only four.

With six medium-sized vats or tanks the time for filling and emptying is less than with three or four of large capacity, and the maximum time any of the milk is held at the pasteurizing temperature is reduced. If six are operated at 7½-minute intervals, the last one will be filling while the first is emptying and the other four will be holding. None of the milk can be held more than 45 minutes, including the time of filling and emptying the tank. Where four tanks are used at 15-minute intervals, the maximum time any of the milk may be held is 1 hour.

The vats or tanks may be filled and emptied by gravity or pumping, or by air pressure or vacuum suction, in which case no pumps are required. Some tanks are filled from the top and others from the bottom. If they are filled from the top, a pipe leading to the bottom of the tank will aid in preventing the formation of foam.

The system of batch holding is quite flexible, because more vats or tanks may be added as the output of the plant increases. With this system, the milk is positively held for the designated length of time.

A modification of the tank-holding system just described consists of a series of four tanks in which filling and emptying is controlled by a revolving mechanism located above and controlling all four tanks. There are no valves attached to the tanks, the filling and emptying being accomplished by air pressure and vacuum.

In another modified system the milk from each tank, after it has been held 30 minutes, is released by air to an auxiliary tank, from which it is pumped to the cooler. Thus, with this system valves and pumps are required only for the auxiliary tank.

As shown in table 8, of a total of 304 plants, 45 used coil vats, 116 spray vats, and 93 used tanks as holders. As a rule these holders were automatically operated and the temperature of the milk automatically controlled.

TABLE 8.—*Number of plants of different sizes using specified types of holders in pasteurizing milk, and number using high-temperature, short-time process, in a total of 304 plants*

Range in quantity of milk handled daily (gallons)	Plants	Plants using specified type of holder in pasteurizing milk by the holder process						Plants using high-temperature, short-time process
		Batch [1]			Pocket [2]		Continuous-flow [3]	
		Coil vat	Spray vat	Tank	Stationary	Revolving		
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
500 or less	47	10	24	12				1
501 to 1,000	46	13	23	8			1	1
1,001 to 2,000	43	9	25	8				1
2,001 to 3,000	29	3	10	12	1	1	1	1
3,001 to 5,000	44	6	11	17	1	4	4	1
5,001 to 10,000	42	2	12	16		5	5	2
10,001 to 20,000	22	1	5	8	1	2	2	3
Over 20,000	31	1	6	12		6	6	
Total	304	45	116	93	3	18	19	10

[1] Small plants may have only 1 vat or tank. When several vats or tanks are arranged in batteries, and operated in rotation, the flow of milk to the cooler is continuous. (See page 20).

[2] Though pocket holders operate on the 30-minute holding period for each pocket, they are in effect continuous holders.

[3] These holders were all of the long-flow tubular type.

POCKET HOLDERS

Pocket holders also hold the milk positively for the desired period at the pasteurizing temperature, and consist of a single unit with several compartments, each compartment being a small, individual holder. There are two types of pocket holders, the stationary and the revolving holders.

In the stationary type (fig. 8) each compartment has its own inlet and outlet valve. These valves are operated by a mechanism which is so timed that the milk in each compartment remains 30 minutes before the outlet valve is opened and the milk released to the cooler. As there are usually eight compartments, none of the milk is held more than about 40 minutes. This type of holder requires a considerable amount of sanitary piping as well as a large number of valves, and is not in general use (see table 8). Such holders should be checked periodically to see that the control mechanisms are operating accurately and that the valves open and close properly.

The revolving pocket-type holder (fig. 9) also consists of a single unit with compartments, usually eight. As the holder revolves, the different compartments are filled in turn from the bottom through a single special valve. The tank revolves slowly and the timing is automatically controlled so that the compartment filled 30 minutes before is emptied through another port of the same valve at the bottom of the holder. The tank containing the eight compartments is insulated, so that the pasteurizing temperature of the milk is maintained during the holding period. Some of the advantages of this type of holder are that only a small amount of floor space is required; there is a minimum of foam formation, because the milk enters at the bottom; and there are a minimum of valves and piping to be cleaned.

Operation is completely automatic, and as the compartments are of comparatively small capacity the maximum time that any of the milk can be held is only about 40 minutes. As indicated in table 8, these holders are used principally in large plants.

CONTINUOUS-FLOW HOLDERS

Several different types of continuous-flow holders were introduced soon after the holder process of pasteurizing was recognized. One of these consisted of a tank divided into compartments so constructed that the hot milk from the heater entered the compartment at one end, overflowed from one compartment to the next, and was finally discharged to the cooler from the compartment at the other end of the tank. Another early type consisted originally of one vertical or upright tank and later of two or more of these tanks. The milk from the heater entered at the bottom of the tank and was discharged to the cooler from the top of the tank where only one tank was used, and where more tanks were used it overflowed from one to the next. As it took 30 minutes to fill the tanks before any milk was discharged to the cooler, it was assumed that all the milk would be held uniformly for 30 minutes. However, with such holders, whether one or more tank be used, some of the milk may pass through the holder within a few minutes after it enters. This was definitely proved by the Bureau of Dairy Industry in tests performed on both types of holders. Inoculations of a pure culture of the organism, *Serratia marcescens* (*Bacillus prodigiosis*) were introduced at the entrance of the holder, and samples were immediately taken at the discharge end of the holder, then at 5-minute intervals. As this organism produced colonies of a red color, it could be readily identified. It was observed to appear at the discharge end within a few minutes after it entered the holder, thereby showing that milk was not being held accurately for the required length of time. All holders of such types have since been condemned by health departments and are no longer in use.

A third type of continuous-flow holder is the long-flow, tubular type. This consists of a series of relatively large tubes which are so connected at the ends that the milk passes from one tube to the next. The milk from the heater enters one end of a tube at the bottom of the unit, and is discharged to the cooler from the last tube at the top of the unit. The entire unit is jacketed, so that the temperature of the milk is maintained. Tests performed on this type of holder showed that all milk is held accurately for the 30-minute period, provided the pump that forces the milk through the apparatus is operated at the proper speed. Therefore the pump must be of the proper size and operated at the desired rate. This is the only holder of the continuous-flow type now in general use. In the 19 plants that were using continuous-flow holders (table 8) all were of the long-flow tubular type.

COOLERS

After the milk has been heated and held for 30 minutes, it must be cooled immediately. For cooling milk after pasteurization, two types of coolers are in general use, the external- or surface-tubular and the internal-tubular. Surface-tubular coolers may be of the single-tubular type or of the cabinet type, also known as the wing or fan type.

Plate heat exchangers, which are described under Heaters, are also used to cool the milk after pasteurization, the hot, pasteurized milk being cooled by the cold, raw milk, cold water, or brine passing on the opposite side of the plates.

SURFACE-TUBULAR COOLERS

The surface-tubular cooler (figs. 21, 23, and 24) consists of a series of tubes, usually constructed of tinned copper or stainless steel, arranged in a vertical tier. The milk flows from a distributing pipe or trough over the tubes in a thin film, and collects in a trough or tank at the bottom of the cooler, from which it flows by gravity to the bottle fillers. The cooling medium is forced through the inside of the tubes. Water is generally used in the top section of tubes and refrigeration in the lower or last section. There may be two independent sections for the circulation of water for more efficient precooling. The cold, raw milk may be used as the cooling medium in the top section if milk-to-milk regeneration is used. Covers may be used over the outside of the cooler (fig. 22) to protect the milk from any contamination from outside air and to reduce evaporation during the cooling. Also, the cooler, after being washed, can be steamed more effectively if it is enclosed.

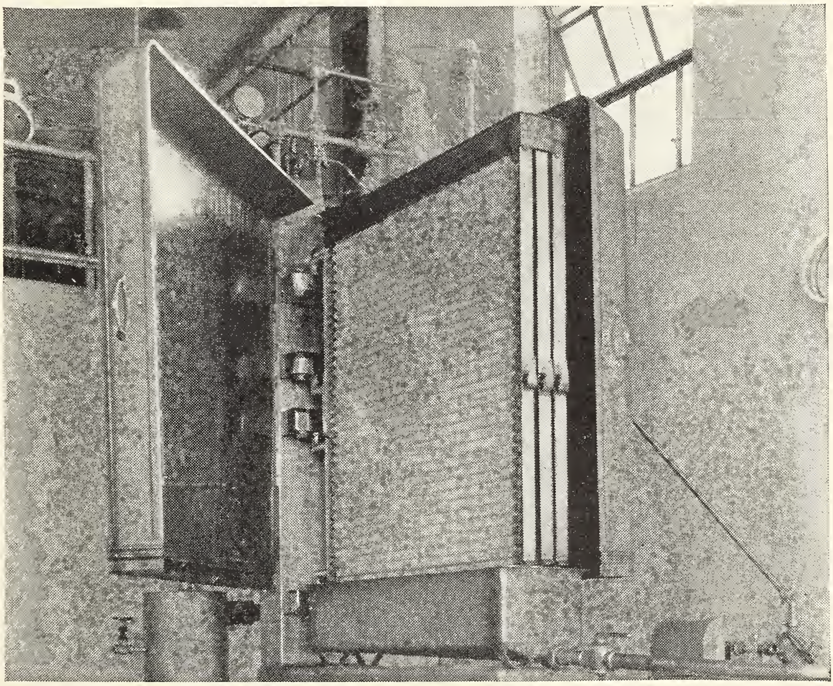

FIGURE 11.—Milk cooler of the cabinet, wing, or fan type.

Surface coolers of the cabinet type, also called wing- or fan-type coolers, consist of a series of surface-tubular coolers assembled into one unit. The number of sections or wings depends on the capacity desired. This type of cooler (fig. 11) requires only a relatively small floor space, and is easily accessible for cleaning.

Internal-tubular coolers are similar to internal-tubular heaters, which were previously described. The hot milk passes through a series of pipes which are themselves surrounded by pipes or jackets through which the cooling medium flows countercurrent to the milk inside the inner tubes. The cooling medium is usually cold water in the first section with artificial refrigeration in the other sections. In this cooler the milk is fully enclosed, so that there is practically no loss from evaporation and no exposure to outside air. It may be steamed effectively by introducing live steam into the tubes. An internal-tubular cooler is shown in figure 12 on page 30.

The types of coolers used at 301 plants are shown in table 9. The surface-tubular cooler was most commonly used, with the cabinet type predominating at the larger plants.

Table 9.—*Number of plants of different sizes using specified types of coolers for cooling milk after pasteurization*

Range in quantity of milk handled daily (gallons)	Plants	Plants using specified type of cooler				
		Surface-tubular coolers	Surface-tubular coolers of cabinet or fan type	Internal-tubular coolers	Plate heat exchanger	Coolers of Chilly-king type
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
500 or less	48	41	4	3		
501 to 1,000	44	37	5	1	1	
1,001 to 2,000	39	27	10	1		1
2,001 to 3,000	28	17	9	1	1	
3,001 to 5,000	44	24	14	3	2	1
5,001 to 10,000	45	17	16	9	1	2
10,001 to 20,000	22	5	11	3	3	
Over 20,000	31	7	13	5	6	
Total	301	175	82	26	14	4

COOLING MEDIUMS USED IN MILK COOLERS

There are four different mediums used for the final cooling in milk coolers; namely, brine, direct-expansion ammonia, sweet water, and ice water. With the direct-expansion ammonia system, the liquid ammonia as it comes from the compressor is allowed to pass through an expansion valve into the cooler tubes and is thus changed to a gas; the change from the liquid state to gas causes absorption of heat from the hot milk. With the brine system the cold brine is pumped from a brine tank or brine cooler through the cooler tubes. The temperature of the brine is maintained by direct-expansion coils in the brine tank or cooler. Sweet water is water that has been cooled by brine or direct-expansion ammonia. Where ice water is used, the larger plants usually manufacture the ice in the milk plant (see table 16, on page 39).

The mediums used for final cooling in milk coolers at 326 plants, and the number of plants using the different mediums, are shown in table 10.

The results in table 10, based on a recent survey, indicate that nearly one-half of the plants use brine, but many are using direct-expansion ammonia or sweet-water cooling. Comparison with the results of a similar survey made 10 years ago, and published in a former (1932) edition of this circular, showed there has been a considerable increase in the use of the two latter mediums. At that time, in a total of 301 plants, 234 were using brine and only 57 direct-expansion ammonia.

TABLE 10.—*Cooling mediums used for final cooling after pasteurization at 326 plants of different sizes*

Range in quantity of milk handled daily (gallons)	Plants	Plants using—			
		Brine	Direct-expansion ammonia	Sweet water	Ice water
	Number	*Number*	*Number*	*Number*	*Number*
500 or less	47	31	11	4	1
501 to 1,000	47	29	11	7	
1,001 to 2,000	47	19	14	13	1
2,001 to 3,000	29	16	9	4	
3,001 to 5,000	49	23	15	11	
5,001 to 10,000	49	26	18	5	
10,001 to 20,000	26	12	7	6	1
Over 20,000	32	17	7	4	4
Total	326	173	92	54	7

Some of the advantages of the use of direct expansion over brine are: (1) Lower initial investment; (2) less equipment to operate and maintain; and (3) less loss of refrigeration, as the refrigerant goes directly to the cooler and not through a secondary brine medium.

There should be a saving in the initial cost with direct expansion, although a refrigerating machine of approximately 25 percent greater capacity might be necessary, because the extra cost of the larger machine would be less than the cost of a brine cooler, brine storage tank, and brine pump. Furthermore, according to Bowen,[1] the power required per ton of refrigeration is usually 25 to 30 percent less for the direct-expansion than for the brine system. Also, the direct-expansion equipment occupies less building space. In many plants that do not desire to purchase a larger compressor when more refrigeration becomes necessary, it may be desirable to run the old machine continuously, and in such a case there is little advantage in use of brine.[2] On the other hand, brine has the advantage of greater elasticity and flexibility, and at plants where the compressor is not operated continuously the brine can be stored for use after the machine has been shut down; also brine can be used with all types of cooling equipment. Sweet water has the advantage that its temperature can be controlled accurately, so that there is no danger of milk freezing on the pipes where it is used. Also, there is no danger of the tubes being corroded. With this system, a large tank with cooling coils is necessary, because the minimum temperature of the water (not below 32° F.) is comparatively high. Ice water is used only in special cases.

Whatever cooling medium is used for the final section of the cooler the use of regeneration will save considerable refrigeration. If regeneration is not used, the use of water in the first section of the cooler to reduce the temperature of the hot, pasteurized milk will save much refrigeration.

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[1] BOWEN, JOHN T. REFRIGERATION IN THE HANDLING, PROCESSING, AND STORING OF MILK AND MILK PRODUCTS. U. S. Dept. Agr. Misc. Pub. 138, 59 pp., illus. 1932.

[2] In at least one city a fire-department ordinance prohibits the use of the direct-expansion system, if the cooling unit is on a floor above the compressor.

HIGH-TEMPERATURE, SHORT-TIME PASTEURIZATION

High-temperature, short-time pasteurization, in which every particle of milk must be heated to not less than 160° F. for a period of not less than 15 seconds, differs from the old flash heating system in that the temperature of the milk is positively and accurately controlled, and the milk is held positively at the pasteurizing temperature for not less than 15 seconds. Its use is permitted, as previously stated, in various municipalities where State regulations have recognized this process.

The plate heat exchanger, as already described, is especially adapted for this process, and is the heater most commonly used with it. Other types of continuous heaters may be used, provided they have the proper automatic controls. Equipment for heating the milk to the pasteurizing temperature by electricity is also adapted for use with this process, and was the first to be used with it. In all equipment for high-temperature, short-time pasteurization the rate of flow and the temperature of the milk must be under precise control, and flow-diverting valves or automatic pump stops must be provided to bypass or check the flow of milk if the temperature should fall below 160° F. The equipment requires less floor space than that used for the holder process, and it can be readily cleaned.

USE OF REGENERATION IN HEATING AND COOLING MILK

Regeneration in pasteurization can be used to good advantage with either the holder process or the short-time, high-temperature process. Marked economies in heat and refrigeration may be effected in large plants, especially, although regeneration can be applied effectively in smaller plants also. Either the milk-to-milk or the milk-to-water-to-milk system of regeneration may be used. With the former system the equipment is so arranged that the cold, raw milk directly precools the hot, pasteurized milk and is itself preheated by the hot milk. This is accomplished by passing the two milks on opposite sides of a dividing wall or a pipe in opposite directions. With the plate heat exchanger, the cold, raw milk flows on one side and the hot, pasteurized milk in opposite direction on the other side of the plates. It is also possible to use milk-to-milk regeneration by pumping the cold, raw milk through the tubes of the first section of the milk cooler over which the pasteurized milk is flowing. This is not recommended, because the raw milk is under greater pressure than the pasteurized milk and any leakage might contaminate the pasteurized milk. Where open-surface, tubular heaters are used, the hot, pasteurized milk may be pumped through the inside of the tubes of the first section of the heater, while the raw milk is flowing down over the outside of the tubes. Other arrangements may be used with milk-to-milk regeneration. With any type of equipment for milk-to-milk regeneration, however, the pressure on the pasteurized milk should always be greater than that on the raw milk when the two are passing on the opposite sides of a pipe or metal wall. The surfaces with which the raw or the pasteurized milk comes in contact must also be of sanitary construction and thoroughly cleaned. The plate heat exchanger is especially well adapted to milk-to-milk regeneration, provided the proper checks are installed so that the pressure on the pasteurized milk is always greater than that on the raw milk.

With the milk-to-water-to-milk system, the water that comes from the cooler and has been heated by the hot, pasteurized milk may be pumped through the first section of the heater to preheat the raw milk. Similarly, cold water from the heater may be used to precool the hot, pasteurized milk.

Results obtained with both systems of regeneration by plants using the holder process and the high-temperature, short-time process are shown in table 11.

Table 11.—*Temperatures to which milk is heated and cooled by regeneration at various pasteurizing plants*

System of regeneration and pasteurizing process used	Plants	Incoming raw milk						Pasteurized milk					
		Temperature before preheating		Temperature after preheating by regeneration		Degrees added by regeneration		Pasteurizing temperature		Temperature after precooling by regeneration		Degrees cooled by regeneration	
		Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
Milk-to-water-to-milk system with—	*No.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
Holder process	34	47.4	35–65	102.6	80–130	55.3	25–80	143.6	142–145	88.6	130–65	56.2	9–83
High-temperature, short-time process	2	40.0	......	97.5	95–100	57.5	55.60	158.0	156–160	93.0	96–90	65.0	64–66
Milk-to-milk system with—													
Holder process	47	44.5	38–65	113.6	90–130	70.9	40–84	143.6	142–145	78.6	120–52	64.8	24–91
High-temperature, short-time process	6	50.3	42–60	124.5	90–140	74.8	52–85	160.9	160–162	85.3	140–70	75.3	20–92

As the milk-to-water-to-milk system is less direct than the milk-to-milk system, more efficient results are obtained with the latter system. At some plants the milk is preheated by regeneration before it is filtered or clarified. Temperatures used in clarifying and filtering milk are shown in table 4 on page 8.

Other Systems of Pasteurization

IN-THE-BOTTLE PASTEURIZATION

Several types of apparatus designed to heat, hold, and cool the milk in the bottle have been introduced in the past. Tests performed with most of them, however, have shown that milk cannot be heated uniformly throughout the bottle with this system, and in-the-bottle pasteurizers are no longer used.

PASTEURIZATION BY ELECTRICITY

Equipment for pasteurizing milk by means of electric current has been greatly improved since the first device of this type was developed some years ago, and is now used in some plants, especially for high-temperature, short-time pasteurization. Usually the milk is preheated to about 130° F. by regeneration, being passed either through a plate heat exchanger or the first section of a tubular cooler over which the hot pasteurized milk is flowing, so that very little heat has to be supplied by the electric heater after the system is in operation a short time. The hot, pasteurized milk is also usually precooled by regeneration to a temperature where only a small portion of the total cooling must be done by refrigeration. A variable speed milk pump is used to force the milk through the apparatus and its speed changes automatically with the temperature of the milk; it also has an automatic stop that checks the flow of milk if the temperature falls below the point desired. The equipment is compact and requires only a small floor space, and it can be easily cleaned. Whether the system of heating milk by electricity to pasteurize it is economical as compared to steam or hot water will depend largely on the rate at which electric current can be provided. Although this system is used principally with high-temperature, short-time pasteurization, it may also be used with the holder process.

Materials Used in Pasteurizing Equipment

In determining what are the most desirable materials for milk-contact surfaces of pasteurizing equipment, the principal requirements that such a material must meet are: (1) No possibility of imparting an off-flavor to the milk or of setting up any chemical or electrolytic action; (2) effective medium for heat transfer; (3) ease of cleaning, and (4) durability.

Tinned copper has been used for many years in the manufacture of pasteurizers, coolers, and other equipment that comes in contact with milk. As long as the tin coating remains on the copper this material will give good results. The tin will impart no objectionable flavor to the milk and is easily cleaned. However, under constant use the coating tends to wear off in places, and the exposed copper may cause an electrolytic action and will often impart an off-flavor to the milk, usually designated as "oxidized," "cappy," "tallowy," etc. For that reason where tinned copper is used it should be kept in good repair at all times.

Stainless steels which contain various proportions of chromium and nickel in combination with the steel, are entirely satisfactory and former difficulties in connection with the fabrication of this material have been largely overcome. It will not corrode and will not impart an off-flavor to the milk. It is very durable and can be easily cleaned and takes on a bright polish.

Glass-coated steel is also satisfactory for pasteurizing equipment. It imparts no off-flavor to the milk and is easily cleaned. Care should be taken in cleaning equipment of this material, and washing solutions containing a strong caustic compound should not be used. Rough usage may cause chipping of the glass coating, which is difficult to repair.

Nickel is not used in pasteurizers and coolers as much as formerly. It is satisfactory for most of the equipment in the plant, but it is relatively more soluble in milk than the other materials mentioned and it may give an off-flavor to the milk when used in coolers, especially in cooling from the pasteurizing temperatures down to about 65° F.

Factors to be Considered in the Selection of Pasteurizing Equipment

In the selection of pasteurizing equipment of the proper design and construction the principal requirements are that the equipment will heat every particle of milk to the pasteurizing temperature for the required length of time, and at the same time impart no injury to the flavor, creaming ability, or other property of the milk.

There must be no "dead ends" or pockets where any of the milk is not heated. All heating and holding equipment must be insulated or jacketed, so that the required temperature of the milk can be maintained. Outlet valves must seat flush with the wall of the pasteurizer or holder and must be so constructed that should any leakage occur it will drip to the floor rather than pass on to the cooler. Inlet valves should be similarly protected against leakage into the pasteurizing equipment.

All operations should be automatic, as far as possible. The temperature of the milk should be controlled automatically by thermostatic units and devices for flow diversion of underheated milk and automatic pump stops provided where necessary. All equipment should be equipped with recording and indicating thermometers with the scale divisions of sufficient size to be easily read.

The temperature and method of applying the heating medium should be such that none of the milk is overheated with resulting injury to its creaming ability and flavor.

Where regenerative heating and cooling is used there should be proper safeguards against leakage of unpasteurized milk into the pasteurized milk by the use of leak protector grooves or other device and by having the pressure on the pasteurized milk or heat transfer medium at all times greater than that on the raw milk.

Other factors to be considered are proper capacity, floor space required, ease of cleaning, and avoidance of foam.

The equipment should be of sufficient capacity to handle the daily output of the plant in the time desired. It is also desirable that it be of such a design that an increase in output can be handled by adding more units. Vat or tank units are adaptable to small plants, and as the business increases more units may be added. These vats or tanks may also be used for other purposes.

Equipment using a small floor space has marked advantages, especially where space is limited.

The apparatus should be as simple and compact as possible with no inaccessible parts, so that it can be readily cleaned and treated either with steam or hot water or a chemical agent. All corners should be smooth and there should be no crevices in the milk contact surfaces. All joints should be electrically welded.

The equipment, including any milk pumps, should be so designed that the formation of foam will be avoided as much as possible, and where foam does form provision should be made for heating it.

Before installing a pasteurizing outfit it is well to get the advice of the local health department.

FILLERS AND CAPPERS

Rotary bottle fillers and cappers are now used almost entirely except in very small plants. Rotary fillers are either of the gravity type or the vacuum type. In fillers of the gravity type (figs. 12, 18, and 19) the circular tank which contains the supply of pasteurized milk, has the filling nozzles fixed to its bottom so that they revolve with the tank. The empty bottles are fed into the machine from a conveyor, and are automatically centered in the bottle supports, which also revolve. As the bottle support revolves it is automatically raised, so that the mouth of the bottle is forced against the filling nozzle, which releases the milk. The nozzle has a rubber gasket that fits tightly around the mouth of the bottle so that no milk can leak out. When the bottle has traveled one full revolution of the tank, the support is automatically lowered and the valve closes and is ready for another empty bottle. The filled bottle is conveyed to the rotary capper which automatically seals it. While the bottle was being filled the displaced air was escaping through a small tube which extends from the bottom of the filling nozzle or valve to the top of the tank above the milk level. In the latest machines any milk retained in the air tube after the bottle has been filled and the valve closed, will remain in the tube until the valve is again opened by the pressure from the next bottle. The milk in the supply tank is kept at a constant level by a float. The capacity of the machine depends on the size of the tank and the number of valves. It will range from about 20 quarts per minute with a six-valve machine to 120 or more quarts per minute with the large machines. Slight adjustments are made for filling pints and half pints and slightly more of the smaller bottles can be filled per minute. Small rotary fillers which will fill about 16 quarts per minute are also available. In most of the larger plants the conveyor system for handling bottles delivers the washed bottles automatically to the bottling machine, and automatically carries away the filled bottles from the capping machine, as for example in figures 12, 18, and 19. In small plants (figs. 7 and 22) the empty bottles may be placed on the filling-machine carrier and the filled bottles taken from the rotary capper by an attendant.

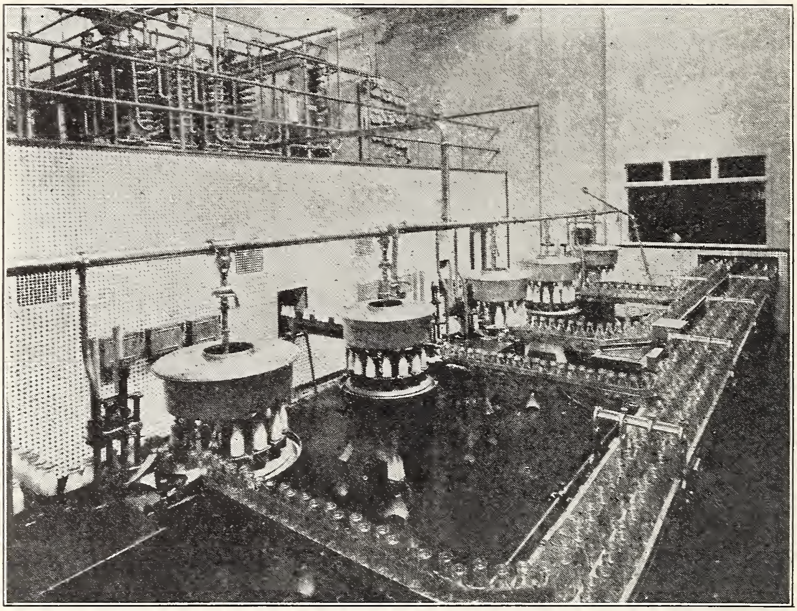

Figure 12.—View in bottling room, showing rotary fillers, heater, cooler of internal-tubular type, and continuous-flow holder.

The vacuum-type rotary filler (fig. 13) was first used in England. In general appearance it is similar to the gravity rotary filler, but the principle of operation is quite different. The milk supply drops from the rotary tank to a float tank which is slightly below the level of the tops of the milk bottles. Individual milk pipes lead from the float tank to the filling heads, which have rubber rings on them. When the incoming empty bottles are raised against these rings by means of the bottle lifters, operated by compressed air, a seal is formed. As soon as this seal is made, the air inside the bottles is drawn out through the vertical vacuum pipes, and the milk is drawn up from the float tank through the milk pipes into the filling heads or nozzles and is discharged into the bottles. As the bottles fill, the foam is drawn off through the vacuum pipes and into the vacuum tank above. Any excess milk which accumulates in the vacuum tank is automatically lowered to the float tank. At the end of the filling cycle the bottle lifter drops, the full bottle loses contact with the filling head, the milk in the milk pipe siphons back into the float tank, and any milk remaining in the vacuum pipe is drawn up into the vacuum tank by means of the vacuum. If a bottle is chipped, a tight seal cannot be made with the filling head and no milk will flow into it. There is therefore no spillage of milk with fillers of this type. They are obtainable in capacities as high as 155 quart bottles per minute.

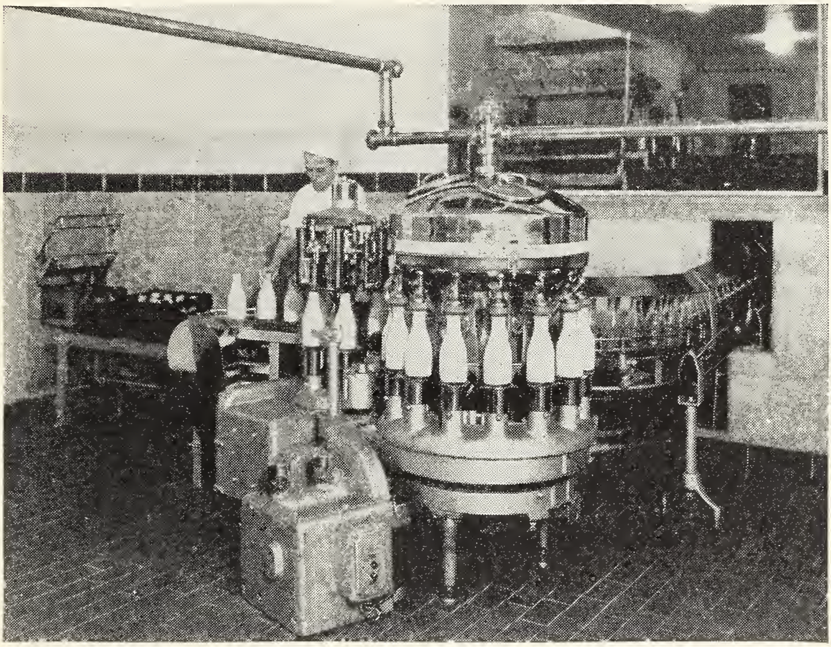

FIGURE 13.—Rotary filler of the vacuum type.

For very small plants, small hand-operated fillers (fig. 14) are available with filling valves similar to those on the gravity rotary filler. The smallest of this type of filler will fill 10 to 12 bottles per minute and has two filling valves and one capper. For small quantities of milk a hand-operated capper (fig. 15) may be used which is entirely sanitary, as the caps are not touched by the hands of the operator.

Table 12 shows that rotary automatic fillers are generally used at plants of all sizes, only 4 small plants out of a total of 288 plants using hand-operated fillers. The use of the vacuum filler is very common in large plants.

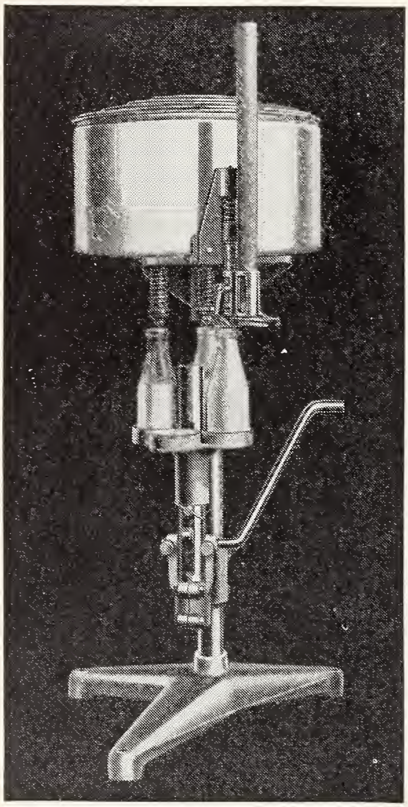

FIGURE 14.—Small bottle filler and capper operated by a hand lever.

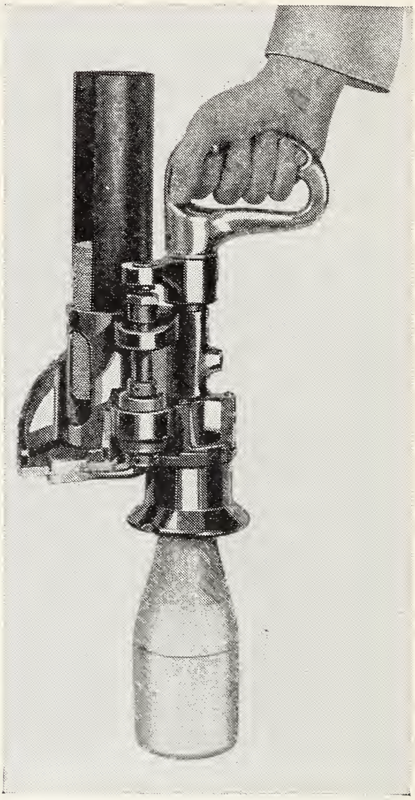

FIGURE. 15—Single-valve automatic hand capper.

TABLE 12.—*Types of bottle fillers and cappers used at plants of different sizes*

Range in quantity of milk handled daily (gallons)	Plants	Plants using specified type of filler and capper		
		Hand-operated	Rotary automatic, gravity	Rotary automatic, vacuum
	Number	*Number*	*Number*	*Number*
500 or less	48	4	44	
501 to 1,000	42		42	
1,001 to 2,000	39		37	2
2,001 to 3,000	26		22	4
3,001 to 5,000	42		37	5
5,001 to 10,000	39		29	10
10,001 to 20,000	25		17	8
Over 20,000	27		17	10
Total	288	4	245	39

BOTTLE WASHERS

The principal types of bottle washers are: (1) The small outfit with revolving brush, rinser, and steamer; (2) the hydraulic-pressure in-the-case washer; and (3) the soaker-type washer.

The small brush washer may consist of a two-compartment wash and rinse tank and a brush which is operated by steam or electric power. After the bottles have been soaked in the tank containing washing-powder solution, each bottle is inserted into the revolving brush by hand, and then put into rinse water in the other compartment or tank. After being rinsed they are placed in the cases. In another type the bottles, after brushing, are returned to the case in an inverted position and placed in a chamber where they receive sprays of hot water or steam or both. The brush method of washing bottles is suitable only for very small plants, and is not in general use. The cost of such an outfit is small, but there is considerable danger of the operator getting his hands injured with broken glass, and other types of washers are more desirable even for small plants.

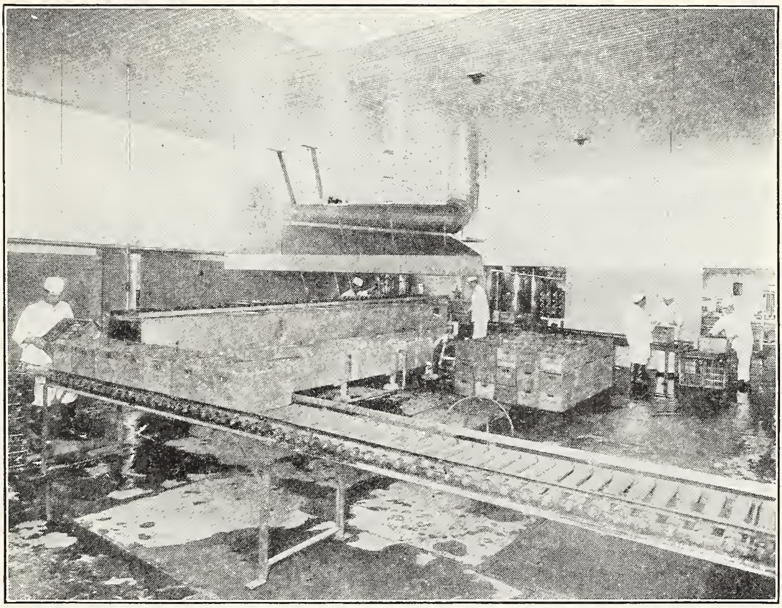

Figure 16.—In-the-case bottle washer with conveyors for moving bottles to and from the machine.

The in-the-case pressure washer (fig. 16) consists of a series of tanks that contain washing solutions and rinse waters, which are pumped through small nozzles into the bottles as they pass through the chamber over the tanks in an inverted position in the case. The temperatures of the various solutions and rinse waters are gradually increased from the first tank to the last. The final treatment may be with steam or with sprays from a tank containing a chemical solution. In-the-case pressure washers require considerable labor, as the bottles must usually be stacked for cooling and rehandled before going to the filling machine, and they have been superseded, especially in larger plants, by soaker-type washers.

A modification of the in-the-case pressure washer adaptable to small plants is available. One of these washers consists of two tanks. A case of bottles (inverted in the case) is placed by hand over the spray nozzles of the first tank, and the washing solution is forced into the bottles. The case of bottles is then moved over the second tank, where the bottles are sprayed with rinse water and steam. Approximately one case per minute can be washed with these small washers.

With the soaker-type washers the empty bottles are removed from their cases and placed in the machine on racks or pockets (fig. 17), and as they pass through the machine they are continuously subjected to rinse waters and washing solutions. In most machines of this type the bottles first pass through a bath of prerinse water, but in some machines this prerinse is effected with sprays. After the prerinse operation the bottles are subjected to a soaking in an alkali solution for several minutes. They are next sprayed inside and out with the alkali solutions. These sprays have a scrubbing effect on the insides of the bottles and assist in preventing film from forming. They are pumped into the bottles with considerable force. With some machines brushes are used. These brushes revolve as they are automatically inserted inside the bottles. The bottles are then sprayed with rinse waters which remove the washing solution. The temperatures of the various rinse waters or solutions as the bottles pass through the machine, are gradually increased up to about 160° F., and then gradually reduced. Since the bottles receive a prolonged washing with a strong alkali solution, it is not necessary to use so high a temperature for effective cleaning as with other types of washers. The final rinse is with cold or refrigerated water and, in some cases, a chemical solution. After the bottles have been rinsed they travel a short distance in an inverted position, so that the remaining water will drain out of them. They are then discharged from the machine in an upright position (fig. 17) to a conveyor, which carries them direct to the bottle-filling machine (fig. 18). Thus the bottles are not handled manually after being fed into the machine. At the discharge end the bottles are inspected to detect any that may not have been thoroughly cleaned.

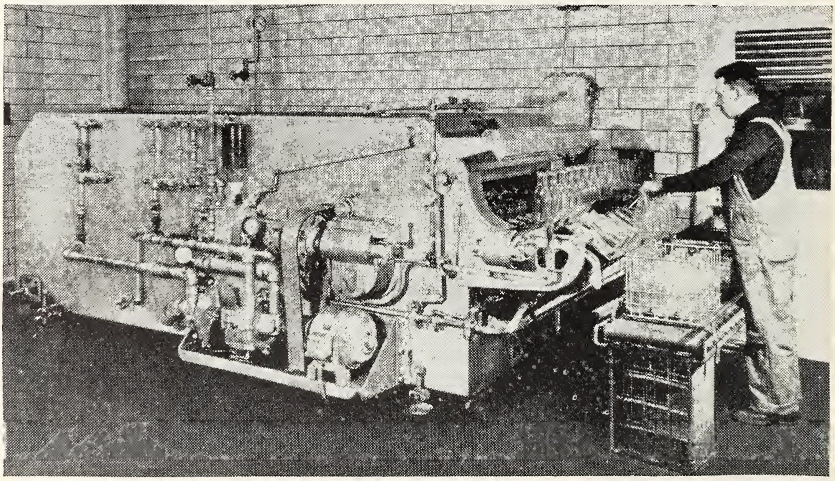

FIGURE 17.—Putting bottles in a soaker-type washer. The washed bottles are being removed automatically by a conveyor, which carries them to the filling room.

The bottle racks or pockets are in rows of from 4 to 12 bottles each, depending on the capacity of the machine. A machine with only 4 rows in width will treat approximately 24 bottles a minute and can be used by comparatively small plants. It can be fed by 1 man, who can also inspect the washed bottles, as with most small machines they are discharged from the feed end. In some of the smaller machines, however, and most of the larger machines, the washed bottles are discharged at the end opposite to that where they are fed in.

In large plants elaborate conveyor systems are used to convey the empty, clean bottles to the fillers and carry the filled bottles, in their cases, to the storage room. Figure 19 shows the conveyor system in a large plant, with several rotary fillers.

The bottle cases, after the bottles have been removed from them, are sent through a case washer, which cleans them thoroughly and delivers them on a conveyor. This conveyor is so arranged that the operator at the filling machine may place the filled bottles in the cases without handling the cases.

Soaker-type washers have also been developed for use in small plants. The bottles, after being removed from the cases, are placed individually in the pockets or carriers and as they pass through the machine they successively receive sprays of rinse water, washing solutions, and more rinse waters. Usually the final treatment is with hot water or steam. After the bottles have been taken out of the machine and returned to the cases, they must be stored to cool before being sent to the filler. In some cases a chemical sterilizer is used in the final rinse. These machines are usually circular in shape and can be

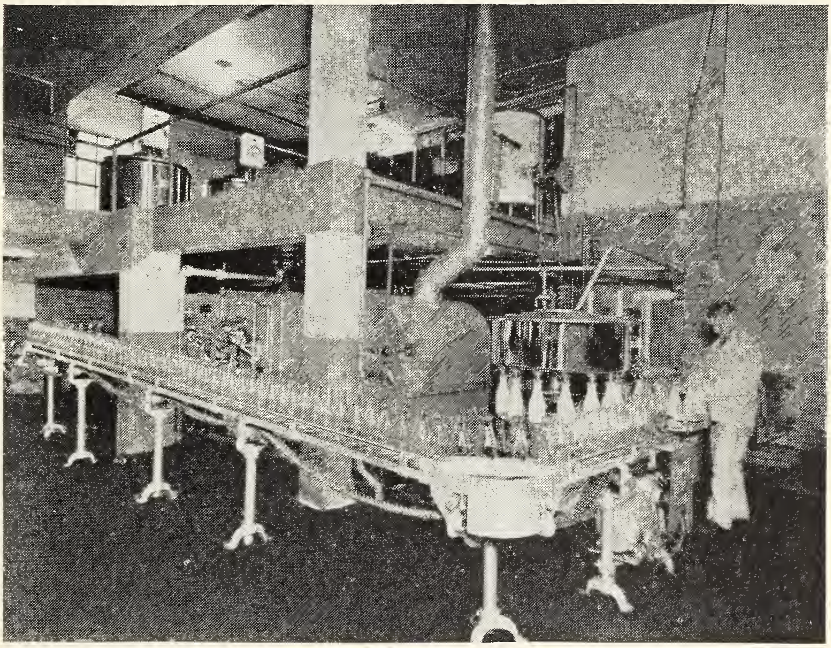

FIGURE 18.—Filling bottles with an automatic filler, as they come from the soaker-type washer.

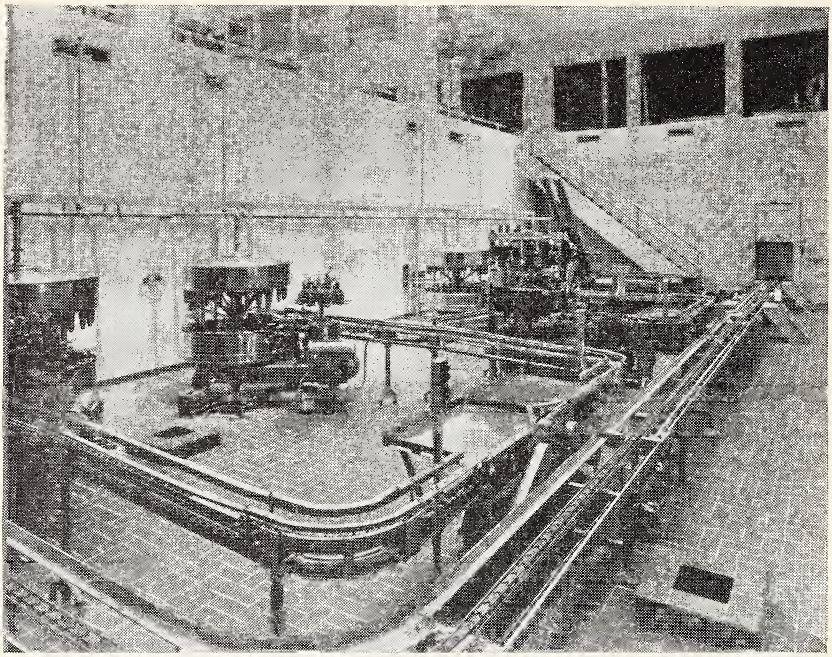

FIGURE 19.—View in a bottling room of a large plant showing rotary fillers and conveyor system. The pasteurizing department is on the mezzanine floor.

operated by one man, who feeds the bottles into the machine and removes them after they are washed at the same end of the machine.

TABLE 13.—*Types of bottle washers used at 285 plants of different sizes*

Range in quantity of milk handled daily (gallons)	Plants	Plants using specified type of bottle washer		
		Turbine- or motor-driven brush	In-the-case pressure	Soaker type
	Number	*Number*	*Number*	*Number*
500 or less	48	14	18	16
501 to 1,000	41	8	11	22
1,001 to 2,000	37	2	6	29
2,001 to 3,000	26		3	23
3,001 to 5,000	41		5	36
5,001 to 10,000	40			40
10,001 to 20,000	22			22
Over 20,000	30			30
Total	285	24	43	218

Table 13 shows the types of washers being used at 285 plants. Even at small plants soaker-type washers are used extensively, and all plants handling over 5,000 gallons of milk daily used this type of washer. In-the-case pressure washers were used at only 43 plants out of a total of 285. The results of a similar survey made about 10 years ago, showed that out of a total of 300 plants, 141 used this type of washer. Studies made by the Bureau of Dairy Industry have shown that much less labor is required [3] and fewer bottles are broken [4] where the soaker-type washer is used, since the bottles go directly to the fillers after being washed with no intermediate handling. (See figs. 12, 18, and 19).

BOTTLE-WASHING SOLUTIONS

The primary requirements of any washing compound to be used in bottle washers are that it must: Have the ability to dissolve all particles of dried-milk solids or foreign materials that may be present; have good rinsing qualities; be an effective sterilizing agent. The compound most commonly used is sodium hydroxide (caustic soda) and usually a 2- to 3-percent solution is recommended. Where several solution tanks are used in the large soaker-type washers, a 3.5-percent solution of caustic soda may be used in the first tank at a temperature of about 120° F. and a 2.5-percent solution in the final tank at a temperature of about 155°. Too strong a caustic solution may cause etching of the bottles and undue wear of the lettering on the bottles. Where the water is hard, trisodium phosphate and sodium carbonate (sal soda) may be used in addition to the caustic soda. Their use will also aid in rinsing the bottles so that they will come from the machine in a clearer and brighter condition. In some small plants where a chemical sterilizing agent is used in the final rinse water, a less caustic washing solution, such as sal soda and trisodium phosphate, may be used. The latter compound has good water-softening qualities and rinses easily. It also has a milder effect on metals than caustic soda. Whatever compound is used the recommendations of the manufacturer should be followed as to the proper quantity for the required results.

POWER PLANT

STEAM BOILERS

The boiler room should be entirely separate from the milk-handling rooms. In large plants the boiler and other power-plant equipment are usually placed in the basement or in a separate building. In small plants the boiler may be in a separate building or in a room adjacent to the bottle-washing room, with a tight-fitting door between. The boiler should be of sufficient capacity to supply all steam and hot-water requirements without being forced.

Table 14 shows the rated capacity of boilers used at 237 plants of various sizes. It will be noted that as the size of the plant increases the boiler horsepower per 100 gallons of milk handled decreases. Table 15 shows that coal is generally used for fuel, though many plants use oil or gas.

Steam engines for power are seldom used in milk plants, and direct-connected motors for each machine in the plant are advisable wherever possible.

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[3] CLEMENT, C. E., LEFEVRE, P. E., BAIN, J. B., and GRANT, F. M. EFFECT OF MILK-PLANT ARRANGEMENT AND METHODS OF OPERATION ON LABOR REQUIREMENTS. U. S. Dept. Agr. Tech. Bul. 153, 40 pp. illus. 1929.

[4] CLEMENT, C. E., BAIN, J. B., and GRANT, FRED M. EFFECT OF PLANT ARRANGEMENT, EQUIPMENT, AND METHODS OF OPERATION IN RELATION TO BREAKAGE OF BOTTLES IN MILK PLANTS. U. S. Dept. Agr. Tech. Bul. 280, 29 pp., illus. 1932.

TABLE 14.—*Size of steam boilers and of refrigerating machinery at 237 plants of different sizes*

Range in quantity of milk handled daily (gallons)	Plants	Milk handled daily per plant	Rated capacity of steam boilers per—		Rated capacity of refrigerating machinery per—	
			Plant	100 gallons of milk handled daily	Plant	100 gallons of milk handled daily
	Number	*Gallons*	*Horsepower*	*Horsepower*	*Tons*	*Tons*
500 or less	31	332	27.2	9.4	11.4	4.1
501 to 1,000	35	758	42.3	5.6	19.7	2.3
1,001 to 2,000	32	1,591	72.1	4.6	22.7	1.4
2,001 to 3,000	21	2,450	92.6	3.7	31.9	1.3
3,001 to 5,000	37	4,141	158.1	3.9	48.9	1.2
5,001 to 10,000	34	7,302	289.0	3.8	72.9	1.0
10,001 to 20,000	21	14,968	294.7	2.0	139.9	.9
Over 20,000	26	31,841	548.0	1.9	233.9	.7

TABLE 15.—*Kind of fuel used at 255 plants of different sizes*

Range in quantity of milk handled daily (gallons)	Plants	Plants using—		
		Coal	Oil	Gas
	Number	*Number*	*Number*	*Number*
500 or less	32	23	4	5
501 to 1,000	40	29	6	5
1,001 to 2,000	35	25	4	6
2,001 to 3,000	26	20	2	4
3,001 to 5,000	38	28	7	3
5,001 to 10,000	37	19	11	7
10,001 to 20,000	21	16	1	4
Over 20,000	26	16	9	1
Total	255	176	44	35
		Percent	*Percent*	*Percent*
Percentage of total		69.0	17.3	13.7

MECHANICAL REFRIGERATION

Practically all plants use mechanical refrigeration for cooling the milk and keeping the milk-storage room cold. In the case of small plants it is sometimes difficult to decide whether to purchase mechanical refrigerating machinery or depend on ice. Some factors that must be considered are the price of ice, the quantity required each day, and the labor and inconvenience in handling it, as compared with the initial cost, operating cost, convenience, and higher efficiency of a mechanical refrigerating plant of suitable size. Mechanical refrigeration has a value that cannot be estimated in dollars and cents because of the higher efficiency and better results obtained. Furthermore, at plants where mechanical refrigeration is used, less ice is required on the delivery trucks, as the temperature of the milk when loaded out is lower than at plants using ice.

Data on the quantity of ice used at plants of various sizes are shown in table 16. Most of this ice was used to ice the milk on the delivery trucks or wagons and branch trucks. The quantity of ice used per 100 gallons of milk handled did not vary greatly regardless of plant size, except with the groups of the smallest and of the largest plants, both of which used decidedly more than the other groups, per 100 gallons of milk. In the largest plants high consumption was partly due to the fact that some of these plants used ice water for cooling the milk and many of them used large quantities for icing the milk on branch trucks, as well as on the delivery trucks. At many large plants the ice is also prepared with flaking machines for icing milk on the branch and delivery trucks.

Table 16.—*Ice manufactured and quantity used at plants of different sizes*

Range in quantity of milk handled daily (gallons)	Plants	Milk handled daily per plant	Total ice used per—		Ice manufactured in milk plant	
			Plant	100 gallons of milk handled	Plants manufacturing ice	Percentage of total ice used
	Number	*Gallons*	*Tons*	*Tons*	*Number*	*Percent*
500 or less	23	347	0.81	0.21	7	11.8
501 to 1,000	33	759	.92	.11	8	26.8
1,001 to 2,000	25	1,626	1.26	.08	6	40.3
2,001 to 3,000	24	2,509	2.57	.10	8	30.7
3,001 to 5,000	35	4,177	3.31	.08	14	51.6
5,001 to 10,000	34	7,300	5.00	.07	14	45.0
10,001 to 20,000	19	15,171	17.30	.11	9	65.0
Over 20,000	26	31,841	51.70	.15	23	79.2

Table 16 also shows the number of plants in each group that manufactured all or a portion of the ice used; also the percentage of the total amount of ice used in each group of plants that was manufactured in the plant. Large plants manufactured a large proportion of the ice used by them.

The rated capacities of mechanical refrigerating machines used at plants of various sizes are shown in table 14 (p. 38), in refrigeration tons per day and according to the quantity of milk handled. With the exception of the machines used in the smaller plants, machines were generally of about 1-ton capacity per 100 gallons of milk handled. Some of the smaller plants apparently had machines of greater capacity than was necessary. Although the large plants manufactured large quantities of ice, they required machines of less capacity per 100 gallons than small plants, both because of more efficient operation and because many of them economize in refrigeration by the use of regeneration in the pasteurizing process.

In general, if the milk is to be precooled with water to about 75° F. and then cooled by refrigeration to below 45° and stored at 35°, a machine with a capacity of about 1 ton per 100 gallons of milk handled will be required. At small plants a slightly larger machine will be required for the direct-expansion system of cooling the milk than if the brine system is used. An estimate of the cost of mechanical refrigerating machines of various capacities, not including brine tanks or pumps or piping to cooling units, is as follows:

Capacity of refrigerating machine, tons:	*Approximate cost, dollars*
1	600 to 800
2	800 to 1,000
3½	1,000 to 1,200
5	1,200 to 1,400
8	1,300 to 1,500
15	2,500 to 3,000
20	3,000 to 3,500

These estimated costs do not include the cost of piping from the machine to the cooler and milk-storage room or the cost of the extra equipment needed where the brine system of cooling is used. Approximately 50 percent should be added for the cost of this equipment. They also do not include costs for freight and installation. A refrigerating machine of the compressor type is shown in figure 20.

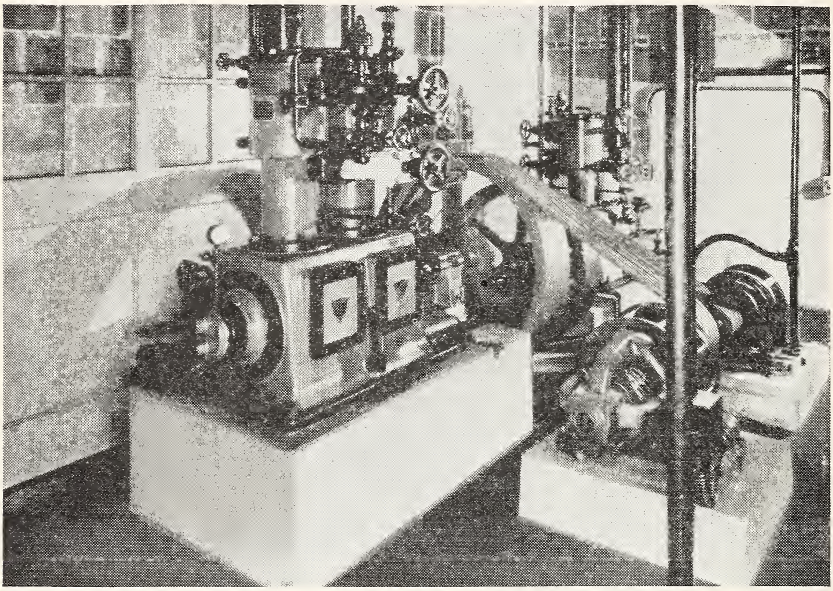

FIGURE 20.—Compressor-type refrigerating machine with direct-connected motor.

METHODS OF COOLING MILK-STORAGE ROOM

Both brine and direct-expansion ammonia are used to cool the milk-storage room. The coils are usually placed on the walls of the room, as there is often not sufficient head room for ceiling coils. Overhead coils may also cause considerable dripping from frost and condensed moisture, which is objectionable. In a survey made several years ago, of 299 plants approximately one-half used brine and one-half used direct-expansion ammonia in the milk-storage room. In recent years unit coolers have been used quite extensively. These coolers are self-contained units which consist of coils and fans. The coils contain either direct-expansion ammonia or brine. The fan forces air through the unit into the room, and also keeps the air in the room in circulation as well as cooling the room. Because of the better circulation of air, it is much drier in the room than in one with brine or expansion coils on the wall or ceiling and no special system of ventilation.

The systems of refrigeration used in the milk-storage rooms of 287 plants of various sizes are shown in table 17. It is evident that direct-expansion ammonia, either by itself or in combination with unit coolers, is much more commonly used than brine, and that a large number of plants are now using unit coolers in the milk-storage rooms.

Table 17.—*Systems of refrigeration used in milk-storage rooms of plants of different sizes*

Range in quantity of milk handled daily (gallons)	Plants	Plants using—					
		Brine	Direct expansion	Brine and direct expansion	Unit cooler	Direct expansion and unit cooler	Brine and unit cooler
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
500 or less	48	12	18	3	5	7	3
501 to 1,000	42	8	14	3	2	12	3
1,001 to 2,000	39	5	[1] 11	4	8	10	1
2,001 to 3,000	26	5	11	2	2	6	
3,001 to 5,000	43	4	14	1	5	14	5
5,001 to 10,000	39	5	9		5	18	2
10,001 to 20,000	22	2	8	1	2	8	1
Over 20,000	28	4	[1] 8	1	5	5	5
Total	287	45	93	15	34	80	20

[1] At 1 plant in this group the air was fanned over outside, direct-expansion coils or bunkers into the room.

EQUIPMENT REQUIRED FOR PLANTS OF DIFFERENT SIZES

On the following pages are lists of the principal equipment required for plants of various sizes and the approximate total cost. These figures on cost are given only as a guide for comparison. The cost of the equipment will depend a great deal on the type of machinery selected, the kind of contract made, and the character of the business. For these reasons, and as prices are continually changing, prices for individual pieces of equipment are given only with the lists for the small-sized plants; and only the estimated total cost of equipment is given with the lists for larger plants. The number of milk cans, bottles, and bottle cases required will depend on the individual plant, but the approximate quantity that would be needed is included in the lists for small-sized plants.

It should be noted that used equipment in good condition can sometimes be purchased at prices much less than those quoted for new equipment. Equipment manufacturers often take in used equipment in trade, recondition it, and sell it with their guarantee. Such equipment can often be purchased at approximately half the cost of new equipment and should be entirely satisfactory where it is desired to keep the initial investment as low as possible.

Information on the construction and arrangement of city milk plants is given in Circular 214 [5] and Circular 228.[6]

Plant of 25 Gallons or Less

If the quantity of milk to be handled is not more than 25 gallons per day, it probably would not pay to invest in a pasteurizer. The can or cans of milk can be set in a small insulated tank containing hot water which is kept hot by adding live steam. The milk should be heated to 142° to 145° F. and held at that temperature for 30 minutes. While the milk is being heated to the pasteurizing temperature it should be agitated gently by stirring, to insure uniform heating. In heating the milk care must be taken not to let the water in the tank get too hot, as milk in contact with the can might then be heated above the pasteurizing temperature, which would give the product a cooked or scorched flavor and also injure the cream line. The temperature of the milk during the heating process should be carefully watched by testing it frequently with a thermometer. When the milk has reached the pasteurizing temperature, the steam should be shut off and the milk held at that temperature for 30 minutes. In order to keep the milk at uniform temperature during the holding period, it may be necessary to pass more steam into the water from time to time and to stir the milk occasionally.

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[5] Grant, Fred M., and Clement, Clarence E. small plants for pasteurizing milk. U. S. Dept. Agr. Cir. 214, 23 pp., illus. 1932.

[6] Clement, C. E., Bain, J. B., and Grant, F. M. construction and arrangement of city milk plants. U. S. Dept. Agr. Cir. 228, 40 pp., illus. 1932.

After the milk has been held at the pasteurizing temperature for 30 minutes, it should be cooled to 45° F. or below as soon as possible. This may be accomplished by letting the hot water out of the tank and adding cold water and ice. The cooling of the milk will be facilitated if it is gently agitated in the can. Somewhat better results can be obtained by using a tubular cooler, and the milk will have a much better cream line. This cooler may be in two sections with separate water connections for each section, so that cold water may be forced through the coils of the top section and ice water or brine through the coils of the bottom section. There should be a perforated trough on top of the cooler to distribute the milk evenly over the cooler, another trough for the bottom, and a small supply tank above the cooler to provide a uniform flow. A circulating pump would be required to circulate the ice water or brine through the lower section of the cooler. A small box should also be provided for the supply of ice water.

From the cooler the milk will flow into a can or a small, hand operated bottle filler. This filler may be a tank of about20-quart-capacity, with a single hand-operated valve. It is unsanitary to cap the bottles by hand, and an automatic hand-operated capper (fig. 15) should be provided.

The bottles must be properly washed, and a wash sink with either a hand brush or one made to revolve by turbine or motor should be provided. After being washed with a good washing solution, the bottles should be rinsed in another tank containing hot water. They may also receive a chemical solution as a final treatment.

A 3- to 6-horsepower boiler will provide the steam for washing bottles and equipment and pasteurizing the milk. If the pasteurized milk is not to be delivered soon after it is bottled, a small insulated storage box should be provided in which the milk, after being well iced in the cases, may be held at a low temperature until sent out on the delivery route.

The principal equipment required to pasteurize and bottle 25 gallons of milk and the approximate cost would be as follows:

1 insulated tank for heating the milk	$20 to $30
1 tubular milk cooler, double-section, complete with water connections, supply tank, troughs, brackets, and ceiling flanges	50 to 60
1 ice-water tank and circulating pump	35 to 50
1 single-valve, hand-operated bottle filler	15 to 25
1 single hand-operated bottle capper	18 to 20
1 wash and rinse tank with hand- or power-operated brush for washing bottles	40 to 100
1 steam boiler, 3- to 6-horsepower	70 to 125
20 bottle crates	30 to 40
5 gross milk bottles	30 to 40
Milk cans	12 to 15
Storage box	50
Estimated total cost	320 to 555

50-Gallon Plant

Pasteurizing vats or tanks of various types with capacities of 50 gallons are available. The milk may be dumped directly into the vat or tank after it has been weighed in the cans. After the milk has been pasteurized it should be pumped or flow by gravity over a tubular cooler, from which it is allowed to flow into a small bottle filler (fig. 21). For this quantity of milk a small, hand-operated filler and capper (fig. 14) may be used.

An insulated storage box will be needed for storing the bottles of milk until they go out on the delivery route. The milk may be kept cold with ice. If mechanical refrigeration is to be provided, the tank from which brine is circulated through the cooler may be located in this storage box, and the brine cooled by mechanical refrigeration. This would increase the total cost of the equipment by $600 to $800 in addition to that of the box itself.

The following is the principal equipment that would be required to pasteurize and bottle 50 gallons of milk daily:

1 platform scale, single beam	$25 to	$30
1 50-gallon tank pasteurizer (motor-driven)	200 to	300
Extras which are desirable and required by most health ordinances:		
Indicating thermometer		30
Recording thermometer		110
Foam heater with thermometer		60
1 milk pump	40 to	60
1 tubular milk cooler (double-section, with water and brine connections, troughs and brackets), capacity 800 pounds per hour	75 to	125
1 brine tank and pump	80 to	100
1 small hand-operated bottle filler and capper	100 to	150
1 small bottle washer	75 to	150
1 8- to 10-horsepower steam boiler	200 to	300
40 bottle crates	60 to	80
10 gross milk bottles	55 to	75
Milk cans	20 to	25
Insulated tank or box for storing milk (without or with a mechanical refrigerating unit	300 to	1,000
Estimated total cost	1,230 to	2,595

Figure 21 shows a view of a plant of 50-gallon capacity.

100-Gallon Plant

Where the quantity of milk handled is only 100 gallons daily, it may be weighed in the cans and dumped directly into the pasteurizing vat or tank (fig. 7). If this practice is not recommended by the local health officials, the milk, after being weighed, may be dumped into a small dump tank from which it will flow by gravity or be pumped to the pasteurizer (fig. 6). If the milk can be dumped into an elevated dump tank the pump will not be necessary. An efficient strainer or filter should be provided at the entrance to the pasteurizer or the dump tank if one is used. This filter may be a home-made device consisting of layers of cheesecloth and cotton or of flannel filter cloth held in place by steel rods. After the milk has been heated and held in the vat or tank at the pasteurizing temperature for 30 minutes (fig. 22), it is run over a tubular cooler. If the pasteurizer is on the same floor level as the cooler, a milk pump must be used; but if the

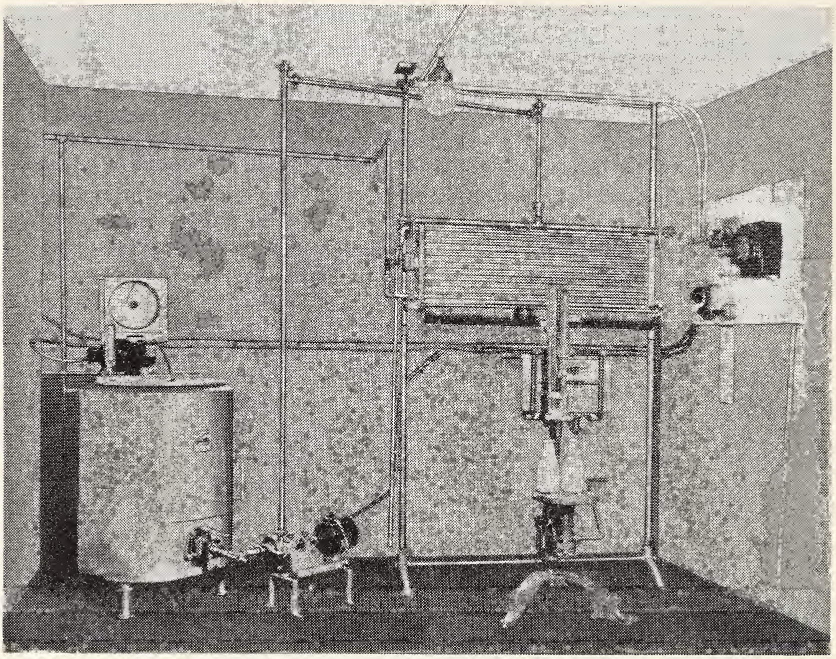

FIGURE 21.—Equipment for pasteurizing and bottling 50 gallons of milk daily.

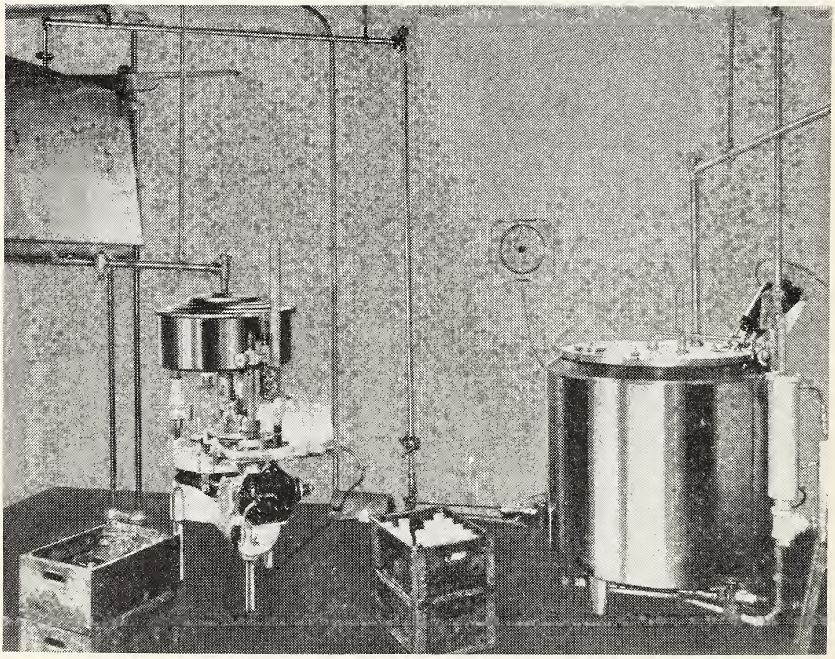

FIGURE 22.—Equipment for pasteuring and bottling 100 or more gallons of milk daily.

pasteurizer is elevated on a mezzanine floor, the pasteurized milk may flow by gravity over the cooler and no pump is required.

The cooler should be large enough to cool the milk in one-half to three-quarters of an hour. When it becomes necessary to increase the output of the plant, two runs may be made with the vat or tank or another unit may be added without increasing the capacity of the cooler or the bottle filler. An automatic bottle filler and capper (fig. 22) of the capacity listed will handle the milk as fast as it comes from the cooler. A small hand-operated filler and capper would cost from $115 to $250, or considerably less than the automatic type, but is less convenient to operate. The bottled milk should be immediately placed in the milk-storage room. Trucks may be used to make the transfer. One man or one man and a helper should be able to operate the plant.

The principal equipment required for a 100-gallon plant is as follows:

1 platform scale	$25 to	$40
1 small dump tank with strainer or filter	75 to	100
1 can wash sink with steam jet	25 to	50
1 pasteurizer (100-gallon vat or tank), complete with motor	350 to	600
1 recording thermometer	75 to	125
1 indicating thermometer	25 to	30
1 sanitary milk pump	60 to	75
Sanitary piping and fittings	50 to	75
1 tubular milk cooler (capacity 1,500 to 2,000 pounds per hour), double-section, with water and brine connections, troughs, and brackets	200 to	300
1 brine tank and brine pump	100 to	225
1 small automatic filler and capper (capacity 16 to 20 bottles per minute)	575 to	800
1 small bottle washer and sterilizer	350 to	550
1 small separator	75 to	125
1 small churn	15 to	20
1 10-horsepower steam boiler, with necessary fittings	250 to	450
Milk cans and bottle crates	150 to	200
Trucks for handling bottled milk in cases	25 to	30
1 Babcock tester (12-bottle size)	30 to	50
Steam and water hose and fittings	15 to	20
Initial supply of milk bottles	100 to	150
Estimated total cost	2, 570 to	4, 015

If mechanical refrigeration is to be used, an additional investment of $800 to $1,200 would be required. A small hand-operated filler and capper costing from $115 to $250 could be used instead of the automatic filler and capper.

If the milk is to be dumped directly into the pasteurizer after it is weighed, the dump tank would not be needed. A floor plan for such a plant, prepared by this Bureau in cooperation with the Bureau of Agricultural Engineering, is shown in Circular 214.[7]

Figure 22 shows a view of the pasteurizing and bottling equipment in a plant of 100-gallon capacity.

250- TO 300-GALLON PLANT

In a 250- to 300-gallon plant the milk may be weighed in the cans and then dumped into a dump tank (fig. 6), from which it will be pumped to the pasteurizer, or a weigh can may be used and the milk dumped directly into it and weighed (fig. 2), in which case it would then be released by gravity flow to a receiving vat, from which it is pumped to the pasteurizer. A filter may be installed in the pipe line between the receiving vat and the pasteurizer or a homemade filter, such as is described for the 100-gallon plant, may be used at the entrance to the receiving vat or the pasteurizer.

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[7] See footnote 5, p. 41.

After the milk has been heated and held in the pasteurizer, which may be a vat of the coil or spray type or a tank pasteurizer, it is sent over the cooler either by gravity or pump, as in the 100-gallon plant. With the equipment outlined it will take approximately 1 hour to cool the milk and fill the bottles. A 300-gallon pasteurizing vat or tank is suggested in the list below, but if desired two vats or tanks of 150 gallons capacity each could be used or two runs could be made with one 150-gallon vat or tank. With the smaller sized pasteurizer a cooler of slightly less capacity could be used. If the output of the plant increases, either another pasteurizer could be added or more runs made with the original vat or tank with no increase in size of the cooler or bottle filler and capper.

The principal equipment required for a 250- to 300-gallon plant is as follows:

1 platform scale	$40	to	$50
1 dump and weigh can	100	to	150
1 receiving vat with strainer	125	to	150
1 sink for washing cans, with rinser and steamer	65	to	80
1 to 2 sanitary milk pumps	60	to	150
1 pipe-line filter	30	to	150
1 pasteurizer (300-gallon vat or tank), complete with motor	1, 000	to	1, 200
1 recording thermometer	75	to	125
1 indicating thermometer	25	to	30
1 tubular milk cooler (capacity 2,400 to 3,000 pounds per hour)	300	to	400
1 automatic bottle filler and capper, complete with motor	600	to	800
1 bottle washer and sterilizer	300	to	500
1 cream separator (capacity 1,000 pounds per hour)	125	to	175
1 small churn	20	to	40
1 mechanical refrigeration outfit (capacity 2½ tons), complete with motor, brine tank, coils, and pump	1, 200	to	1, 500[1]
1 steam boiler (15 to 20 hp.), with necessary fittings and accessories	375	to	550
Milk cans and bottle crates	225	to	400
Trucks, conveyors, etc., for bottles	35	to	60
1 Babcock tester	30	to	50
Sanitary piping and fittings	75	to	100
Steam and water hose and fittings	25	to	35
Initial supply of milk bottles	300	to	400
Estimated total cost	5, 130	to	7, 095

[1] A self-contained refrigerating unit could be purchased for from $800 to $1,000.

Figure 23 shows the pasteurizing and bottling equipment in a milk plant of about 300 gallons capacity.

A floor plan for such a plant is shown in Circular 214.[8]

500-Gallon Plant

In a 500-gallon plant a weigh can is necessary. The milk should flow from the weigh can to the receiving vat by gravity. This may be accomplished by having the receiving-room floor elevated about 4 feet above the pasteurizing-room floor or by placing the receiving vat in a pit below the level of the receiving-room floor; the former arrangement is preferable as it permits more easy cleaning. By the use of dial scales the milk can be weighed quickly and accurately.

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[8] See footnote 5, p. 41.

Either a continuous-flow pasteurizer or the batch system of pasteurization may be used. If the batch system is used, only a small receiving vat will be required, as the milk will be pumped from it directly through a filter or clarifier into the pasteurizing vats or tanks; two vats or tanks of 250- to 300-gallon capacity each would be desirable (fig. 24). After the first vat or tank has been filled and the milk heated, the second vat or tank will be filled while the milk in the first unit is being held, and the system will be nearly continuous.

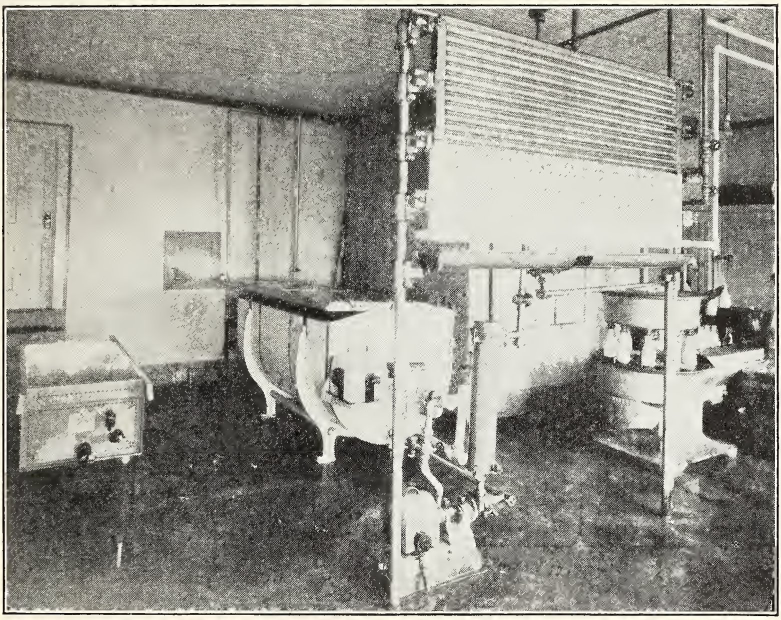

Figure 23.—Equipment in a plant with a daily capacity of about 300 gallons, using vat pasteurizer, surface cooler, and rotary filler and capper.

If a continuous-flow pasteurizer is used, the milk may be preheated in the first section and bypassed to the clarifier or filter before it goes to the final heating unit. Whichever system of pasteurization is used, the cooler and bottle filler should be of large enough capacity to readily handle the milk as fast as it comes from the pasteurizer.

The principal equipment required for a 500-gallon plant is as follows:

1 platform dial scale.
1 weigh can, with cover, strainer, and splash hood.
1 receiving vat (capacity 150 gallons), with cover and agitator.
1 can washer, rinser, and steamer.
2 sanitary milk pumps.
1 filter or clarifier.
1 pasteurizing and cooling outfit, complete with automatic temperature control and recording thermometers.
1 automatic bottle filler and capper, complete with motor.
1 bottle washer and sterilizer.
1 separator (capacity about 2,000 pounds).
1 churn.

1 mechanical refrigeration outfit (capacity 4 to 5 tons), complete with motor, brine tank, coils, and pump.
1 steam boiler (20 horsepower), with accessories.
Milk cans and bottle crates.
Trucks and conveyors.
1 Babcock tester.
Sanitary piping and fittings.
Steam and water hose and fittings.
Estimated total cost, $12,000 to $15,000.

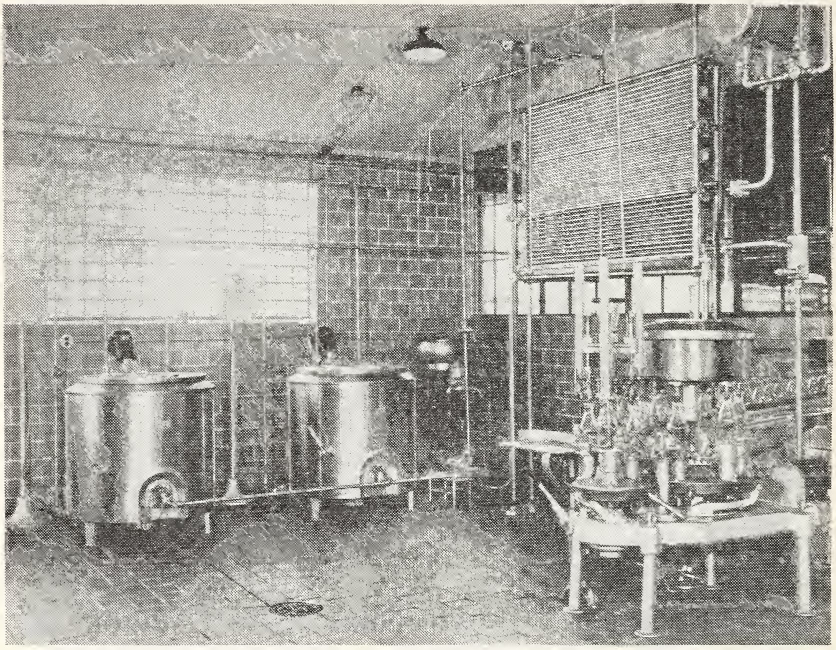

Figure 24.—View in a well-equipped plant having a capacity of 500 or more gallons of milk daily, with two small tank pasteurizers, a surface cooler, and a rotary-automatic filler and capper. The milk is received and weighed at right.

Figure 24 shows the pasteurizing and bottling equipment in a plant of 500-gallon capacity.

A floor plan for a plant of this capacity is shown in Circular 214.[9]

1,000-Gallon Plant

If the milk is to be received in cans from a large number of producers, a two-compartment weigh can will facilitate the receiving and weighing. In a 1,000-gallon plant an insulated raw-milk storage tank is usually desirable, the milk being pumped to it from the receiving vat. Either a continuous-flow system or a batch system of pasteurization may be used in a plant of this size, although batch systems are more common (table 7). If a batch system of pasteurization is to be used, a separate preheater could be installed between the raw-milk storage tank and the filter or clarifier; if a continuous-flow system is used, the milk may be preheated in the first section of the continuous-flow heater, and bypassed through the filter or clarifier before going to the second section of the heater or pasteurizer proper.

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[9] See footnote 5, p. 41.

In using a batch system it is better to have several tanks (or vats) than one larger tank. With three tanks the flow of the milk to the cooler will be practically continuous; the first tank is filled and heated in 30 minutes; while this unit is being held 30 minutes the second unit is filled and heated; then the first is emptied while the second is being held and the third unit filled and heated. Thus continuous operation is maintained with a capacity of 4,000 to 5,000 pounds (500 to 600 gallons) per hour, depending on whether 250- or 300-gallon tanks are used. As in starting the day's run 1 hour will be required to fill, heat, and hold the first tank of milk before any milk is sent to the cooler and fillers, this time must be included in the total required for the run. Approximately 15,000 to 20,000 pounds could be handled in 5 hours. A continuous-flow heater may be used as a "booster" to heat the milk partly or entirely to the pasteurizing temperature before it goes to the pasteurizing tanks or vats, and the time required to pasteurize a given quantity of milk is reduced. The cooler and bottle filler must be of a capacity sufficient to handle the milk readily as fast as it comes from the pasteurizer.

The bottle washer may be either a soaker-type or hydraulic-pressure, in-the-case washer. Washers of the soaker type are more commonly used for plants of this size (table 13, p. 36). With these washers the bottles will go direct to the fillers after being washed. A pressure washer that treats the bottles in the cases could be purchased at less cost than a soaker-type machine. With this washer more labor would be required because of the extra handling necessary. However, the total number of men required to operate the plant would not necessarily be greater, as the same men who wash the bottles may be used in filling them later, while with the soaker washer the bottles will be washed and filled in one continuous operation.

The principal equipment required for a 1,000-gallon plant is as follows:

1 2-compartment dump and weigh can, with cover, strainer, and splash hood and two 4-inch gates.
1 dial scale.
1 automatic can washer, rinser, and steamer.
1 receiving vat, with cover and agitator.
1 milk-storage tank (capacity 800 to 1,000 gallons).
1 clarifier or filter (4,000 to 6,000 pounds per hour).
1 pasteurizing and cooling outfit, with automatic temperature control and recording thermometers (capacity 4,000 pounds per hour).
2 sanitary milk pumps.
Sanitary piping and fittings.
1 automatic bottle filler and capper, complete with motor.
1 automatic bottle washer and sterilizer.
1 cream separator (2,000 to 2,500 pounds per hour).
1 50-gallon cream vat or tank.
1 vat or tank for buttermilk.
1 churn.
1 steam boiler, with necessary fittings and accessories (about 60 horsepower).
1 mechanical refrigeration plant, complete with motor and accessories (about 10-ton capacity).
Milk cans and bottle crates.
Trucks and conveyors.
Chemical and bacteriological apparatus.
Steam and water hose and fittings.
Estimated total cost, $18,000 to $30,000.

Many plants of this size, or even smaller plants, wish to homogenize the coffee cream. A 100-gallon homogenizer would cost approximately $1,600.

Plants of Large Capacity

No attempt is made to list herein the equipment required for large plants or to estimate the total cost of such equipment. The equipment selected will depend on personal preferences, special products to be handled, etc., and there is a wide vareiety of types of equipment available. Large plants which receive milk in cans usually use a two-compartment weigh can that has large outlet valves (fig. 2). This tank may be so arranged that the cans, after the milk has drained from them, may be pushed directly into the can washer. Many large plants now receive the milk from tank trucks or tank cars, so that the receiving equipment listed for the smaller plants would not be adaptable. Such plants usually have several large storage tanks for the raw milk and, in many cases, a similar tank is used for weighing it as it comes from the tank truck or tank car. It is usually released by air pressure from this tank to the storage tanks, which may be located either on the lower floor level where the milk is weighed in or on the pasteurizing-room floor above. Coolers are often provided for cooling the raw milk before it goes to the storage tanks. (See pp. 5 and 6).

Continuous-flow pasteurizers are usually used at large plants, with batch, pocket, or continuous-flow holders; both the heating and holding of the milk being accurately controlled automatically.

Large bottle washers of the soaker type are used. The automatic fillers and cappers are of large capacity (figs. 12 and 19). Separate equipment is required for byproducts, such as cream, buttermilk, and some varieties of special milks; including cream pasteurizing equipment, buttermilk machines, homogenizers, vats for chocolate drink, etc.

Large plants generally require a complete laboratory for making bacteriological and chemical analyses. The principal equipment and supplies required in such laboratories are as follows:

BACTERIOLOGICAL APPARATUS FOR MILK-PLANT LABORATORY [10]

1 autoclave, medium size.
1 dry-sterilizing oven, gas stove, and kitchen oven.
1 incubator, 10 by 8 by 6 inches, inside dimensions.
1 balance, with weights to 5 kilograms.
100 1-milliliter pipettes, graduated in tenths, with an extra tenth above the 0 mark.
1 5-milliliter pipette.
1 10-milliliter pipette.
1 25-milliliter graduated cylinder.
1 100-milliliter graduated cylinder.
1 500-milliliter graduated cylinder.
1 1,000-milliliter graduated cylinder.
2 dozen Erlenmeyer flasks, 1,000 milliliters.
100 Petri dishes, 100 by 10 millimeters.
4 dozen glass bottles, 8-ounce, prescription or French square, with nonabsorbent stoppers.
2 funnels, glass, 6-inch.
1 double boiler, ½ gallon.
1 thermometer (—10° to 100° C.).
1 thermometer (0° to 250° C. for dry sterilizer).
1 dozen glass stirring rods (assorted).
2 Petri dish holders, sheet-iron, 50 dishes.
2 pipette boxes.
1 reading glass, 2½ magnifications, 4 inches.

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[10] The suggested lists of bacteriological and chemical apparatus were prepared with the assistance of J. Frank Cone, associate market-milk specialist, and H. S. Haller, assistant chemist of the Division of Market-Milk Investigations ,Bureau of Dairy Industry.

1 counting chamber with illumination equivalent to that of the Quebec Colony Counter.
1 tallying machine.
1 gas stove, single burner.
2 Bunsen burners.
12 feet of gas tubing, ¼-inch.
2 wax pencils, blue or red.
Colorimetric pH outfit for the range of pH 6.2–7.4 (not needed if dehydrated culture medium is used).

Approximate cost, $500.

CHEMICALS AND ACCESSORIES FOR BACTERIOLOGICAL EXAMINATION

1 liter sodium hydroxide, N/10.
1 liter sodium hydroxide, N.
1 liter hydrochloric acid, N/10.
1 liter hydrochloric acid, N.
Absorbent cotton.
Nonabsorbent cotton.
Canton flannel for filtering.
Filter papers.
Dehydrated tryptone-glucose-extract agar, or tryptone, dextrose, and beef extract.

CHEMICAL APPARATUS FOR MILK-PLANT LABORATORY

1 Babcock milk tester from 12 to 16 bottles, hand- or steam-operated.
3 dozen milk-test bottles, 8 percent.
1 dozen cream test bottles, 50 percent.
2 pipettes, 17.6 milliliters.
1 combined acid bottle and pipette.
1 lactometer (Quevenne).
1 burette, 50 milliliters, graduated in tenths.
1 burette holder.
1 dozen beakers, 150 milliliters.
1 dropping bottle, 30 milliliters.
1 cream-test scale.
1 pipette, 10 milliliters.
1 pipette, 25 milliliters.
½ dozen skim-milk test bottles.

Approximate total cost, from $75 to $100.

CHEMICALS FOR CHEMICAL ANALYSIS OF MILK AND CREAM

Sulfuric acid, commercial, ½ gallon.
Phenolophthalein, 1-percent solution, 100 milliliters.
Sodium hydroxide, N/10, 1 liter.

Small plants should at least have equipment for making the Babcock test for butterfat.

MEN REQUIRED TO OPERATE PLANTS EQUIPPED AT VARIOUS CAPACITIES

Information as to the number of men that would be required to operate plants of various capacities is given in table 18. These data are based on a recent survey of 261 plants, and include only men used in the operation of the plant, with maintenance men and checkers, but excluding office or route employees.

TABLE 18.—*Number of plant employees at 261 milk plants of different sizes*

Range in quantity of milk handled daily (gallons)	Plants	Milk handled daily per plant	Total men per plant	Milk handled daily per plant employee	Milk handled daily per plant employee exclusive of checkers
	Number	*Gallons*	*Number*	*Gallons*	*Gallons*
500 or less	43	316	3.3	103.3	121.0
501 to 1,000	37	764	5.8	161.4	195.7
1,001 to 2,000	33	1,578	9.3	206.9	248.9
2,001 to 3,000	25	2,483	13.1	232.7	278.2
3,001 to 5,000	39	4,150	17.9	264.5	310.1
5,001 to 10,000	38	7,487	28.7	340.2	392.5
10,001 to 20,000	20	15,386	52.9	341.0	396.8
Over 20,000	26	28,751	93.2	344.4	392.6

As the capacity of the plant increases, the quantity of milk handled per plant employee increases. Considerable handling of the cans, bottles, and cases is usually necessary with the equipment provided in small plants, while in large plants equipment is principally automatically operated. Besides the more efficient machinery, the large plants are equipped with elaborate conveyor systems that reduce handling to a minimum.

While the data in table 18 show a close relationship between size of plant and efficiency of labor, there was but little increase in the efficient use of labor as the size of the plant increased above 10,000 gallons of milk daily. However, the number of men required to operate a milk plant also depends on various other factors, such as type of labor used, quantity of byproducts handled, and quantity of various products bottled in containers of different sizes; and detailed information as to such factors in these plants was not obtained.

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